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16. ABSTRACT

Introduction

The design of recycled asphalt concrete mixtures, like the design of any asphaltic mixture, requires the selection of the AC thickness as well as the determination of binder content and gradation to provide the strongest and most durable mixtures.

There are three types of recycling, they are Hot- central plant, Cold - in place, and Surface Recycling. Surface Recycling generally will require somewhat less engineering attention that the Hot or the Cold methods. Also, because it is confined to the top one inch of the roadway surface, structural section strength is generally not significantly affected.

The theoretical strength of any recycled asphalt concrete has been the subject of some debate. Generally, it is now conceded that most properly designed hot recycled mixes will have strength comparable to new asphalt concrete. In the case of the cold mix recycling process, there is growing evidence that once the material has been properly designed, constructed and cured, it too will achieve a structural strength approximately equal to the strength of hot asphalt concrete although it probably will require a surface treatment to resist surface raveling.

Therefore, factors involving structural section design will not be discussed this morning. The discussion will dwell principally on the determination of the correct type and amount of new binder required for hot and cold recycled mixes.

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PROCEEDINGS
ASPHALT CONCRETE RECYCLING SEMINAR

Sponsored by

FHWA and CALTRANS

Sacramento, Calif - Quality Inn - Sept. 15 & 16, 1981

REPORT No 81-21

Agenda

A Seminar on Asphalt Concrete Recycling

September 15 and 16, 1981 - Sacramento, California
September 17 and 18, 1981 - Long Beach, California

Moderator - Raymond A. Forsyth

First Day

10:00 - 10:20	Welcome and Introduction	R. O. Watkins
10:20 - 10:50	FHWA Program	D. A. Bernard
10:50 - 12:00	Design	T. Scrimsher
12:00 - 1:00	Lunch (included in Registration)	
1:00 - 2:00	Quality Control	R. C. Ingberg
2:00 - 3:00	Surface Recycling - Construction	G. F. Whitney
3:00 - 3:15	Break	
3:15 - 4:15	Cold Recycling - Construction	J. F. Wood
4:15 - 5:15	Hot Recycling (Batch Plant) - Construction	W. J. McCullough

Second Day

8:15 - 9:45	Hot Recycling (Drum Mix Plant) - Construction	J. A. Scherocman
9:45 - 10:00	Break	
10:00 - 11:00	Hot Recycling - Case Histories	R. J. Peters
11:00 - 12:00	Cold Recycling - Case Histories	L. Jorgensen
12:00 - 1:00	Lunch (included with Registration	
1:00 - 2:00	Surface Recycling - Case Histories	J. L. Vicelja
2:00 - 3:00	Panel (Question and Answer Period)	D. A. Bernard W. J. McCullough (1) J. A. Scherocman J. L. Vicelja T. Scrimsher (2) J. F. Wood

(1) Sacramento only
(2) Long Beach only

ASPHALT CONCRETE PAVEMENT RECYCLING

INTRODUCTION

ROBERT O. WATKINS

September, 1981

[illegible]

I consider it an honor, and I am also experiencing a certain amount of pride today, to act as the introductory speaker for this seminar. It was about November of last year that, while Chief of the California Department of Transportation Laboratory in Sacramento, I felt the need for better communication between engineers, contractors, consultants and public agencies on the art of recycling asphalt concrete. I discussed this with Harold Schmidt of the Federal Highway Administration and we dreamed up this seminar on recycling asphalt concrete.

Shortly after arrangements were started, however, I was assigned as District Director in San Bernardino. However, from a review of the agenda, it appears that the staff of TransLab and the personnel of FHWA have done an excellent job and put together an informative package.

We need to explore and develop a good process for recycling asphalt pavements. First of all, asphalt costs have increased dramatically over the last several years. In some parts of our country, we have reached the point where the supply of natural aggregates for conventional pavements has virtually been depleted. From these two factors alone, I believe you will agree that there is an obvious need to recycle our old asphalt concrete pavements, since this will require less natural aggregate and asphalt.

I foresee the day when asphalt pavements are recycled and replaced within a single passage by a train of equipment that removes the old pavement, crushes it to size, mixes in a rejuvenating agent, replaces the material and compacts the final pavement. Today, we have the technology to quite satisfactorily perform four of these five functions. We know how to accurately remove existing pavement. Within today's equipment trains, we can size the material, mix in the rejuvenating agent and place the recycled pavement.

We have not been successful in properly compacting cold, recycled asphalt concrete. It is my view that we need to determine some method to add sufficient heat, on the grade, within the equipment train to allow the recycled pavement to be compacted to at least 91 to 92 percent relative compaction. I believe this can be done with existing available equipment by innovative engineers and contractors, and we look to the contractors in California to join this leadership.

The State of California for years had a program for placing "thin blankets" over existing pavements. Initially, these "thin blankets" were intended to provide an improved ride and surface texture. But, as our highway system aged and deteriorated, our Department attempted to expand the "thin blanket" purpose to include correction of modest pavement failure. As you may have recognized, the "thin blanket" overlays were generally unsuccessful when placed over failed pavement.

With the development of a good pavement recycling process, we now have a method to correct the areas of failed pavement prior to the placement of an overlay blanket. We can, therefore, place the entire roadway in a relatively good state of repair and improve the probability that a "thin blanket" will achieve the improved ride and surface texture goals, and provide the public a reasonable service life.

On many four-lane roads, the truck lanes are deteriorated, whereas the passing lanes are in relatively good shape. This is an ideal situation for a recycling effort. The recycling trains can skip along the truck lane, recycling those areas showing distress. This prepares the total roadway for a wearing course of all new material.

On one Caltrans' project, two pavement rehabilitation alternatives were considered. The first one called for placement of a thick asphalt concrete overlay for all four traffic lanes and shoulders of a seven mile stretch of divided roadway. Our analysis of the failed pavement areas concluded that a 0.4' thickness was necessary over the scattered deteriorated pavement sections in the truck lanes. The second alternative was to recycle the scattered sections of deteriorated truck lane pavements, totaling about four lane miles, and then cap the entire 28 lane miles with a relatively thin wearing course of AC to improve ride and surface texture. The cost savings of the recycling alternative are obvious.

Also, we need to understand that, when recycling, it is imperative that we do more engineering than would noramlly be expected for new construction. It is important that we take more samples, perform more tests and establish more construction quality control than is usually the case. Recycling will require a greater dependence on materials engineers and their expertise. Management must be willing to provide training, equipment and resources to meet that need.

When recycling asphalt pavements, I believe it's important that we require more than just a good looking job. While it's possible to get a reasonably good-looking recycled pavement by adding an emulsifier or a cut-back paving asphalt, I believe it's quite important that some steps be taken to rejuvenate the old, brittle asphalt binders from the original construction that are to be included in the recycled pavements to a condition that approximates the characteristics we desire in new, conventional pavements. The asphalt producers are providing specially-formulated recycling agents which should provide service life for recycled pavements which approximates new, conventional pavements. I personally believe that those who feel they can do "just as good a job" with paving asphalt are overlooking the long-term durability that we need in our recycled pavements.

Surface recycling is concerned with the maintenance and restoration of the surface of an existing roadway, airport, etc. When the term surface recycling is used, it is referring to a process which involves re-working the top 3/4 to 1 inch of the existing pavement in place and is called heater-scarification.

The process of removing the surface of an asphalt concrete pavement may involve using heat to soften and break up the surface or it may be broken up by powerful machines which do not use any heat.

Depending on the equipment and procedure used, this could be done as a one phase or multi-phased construction procedure. The processes using heat is heater-planing while the cold processes are referred to as cold-milling and cold-planing, Figure 1.

What is the first thing that must be done to determine if a project is a candidate for surface recycling? Make an evaluation of the pavement deficiencies and catagorize the types of distress.

Cracking	fatigue (load associated)
	reflection
	oxidation (shrinkage)
Pavement Roughness	humps
	shoving
	rutting
Low Coefficient of Friction	polished aggr.
	bleeding
Raveling	
Inadequate Structural Capacity	

Caltrans' Approach to the Design of
Recycled Asphalt Concrete Mixtures

Presented at the Asphalt Concrete Recycling Seminars in Sacramento and Long Beach, California, in September 1981

Thomas Scrimsher
Pavement Research Engineer
Caltrans
Sacramento, California

Introduction

The design of recycled asphalt concrete mixtures, like the design of any asphaltic mixture, requires the selection of the AC thickness as well as the determination of binder content and gradation to provide the strongest and most durable mixtures.

There are three types of recycling, they are Hot - central plant, Cold - in place, and Surface Recycling. Surface Recycling generally will require somewhat less engineering attention than the Hot or the Cold methods. Also, because it is confined to the top one inch of the roadway surface, structural section strength is generally not significantly affected.

The theoretical strength of any recycled asphalt concrete has been the subject of some debate. Generally, it is now conceded that most properly designed hot recycled mixes will have strength comparable to new asphalt concrete. In the case of the cold mix recycling process, there is growing evidence that once the material has been properly designed, constructed and cured, it too will achieve a structural strength approximately equal to the strength of hot asphalt concrete although it probably will require a surface treatment to resist surface raveling.

Therefore, factors involving structural section design will not be discussed this morning. The discussion will dwell principally on the determination of the correct type and amount of new binder required for hot and cold recycled mixes.

Type of Binder

Because salvaged or reclaimed mixtures will contain asphalt that has hardened over the years, any added binder should be a soft paving asphalt or agent that will soften the old asphalt. The agent, when mixed with the aged asphalt, will provide a binder for the recycled mix that is considerably softer than the aged asphalt. This, of course, is desirable if the recycled pavement is to enjoy extended life with minimal cracking. Recently, hydrocarbon products have been made available that will provide this softening effect on the old asphalt. There are a wide range of these softening or rejuvenating agents on the market. Specifications for these products are currently under consideration by the Pacific Coast Asphalt User-Producer Group. Although it is true that only tentative specifications are available today for recycling agents, Caltrans feels that recycling agents should be used whenever appropriate to soften or rejuvenate the old asphalt film. The amount of softening agent to use will depend on the hardness of the old asphalt recovered from the pavement. It will also be dependent on the stability of the mix with a given amount of additive, whether it be asphalt or a recycling agent. We believe the best form of recycling agent is one that can be used as the entire new binder, i.e., a ready mixed product that needs no additional treatment and is added as you would a conventional binder.

Our tentative approach to determine asphalt consistency has been to stay with viscosity measurements as opposed to penetration measurements. We then attempt to design so that the final binder in the recycled mix will have a viscosity between 2000 and 8000 poise or about 4000 poise for either hot or cold recycling. Generally this can be achieved easily with hot recycling because the addition of virgin aggregate permits the addition of substantial amounts of recycling agent. Occasionally, however, if the old asphalt is relatively soft, such as an old road mix might be, then instead of a high viscosity softening agent, a low viscosity paving asphalt may be required to provide a viscosity greater than 2000 poise. In the case of cold recycling, the new binder content is relatively low. Because the old asphalt being recycled is usually quite hard, the lowest viscosity softening agent available today may not provide a recycled asphalt with a viscosity less than 8000 poise. We feel a recycled product should contain a binder less than 8000 poise if we are to provide a degree of durability to make recycling worthwhile. In other words, we want to improve the durability of the old asphalt and not simply recycle the problem of hard brittle pavements. If such a condition occurs wherein the old asphalt cannot be softened below 8000 poise, then one option would be to require the addition of virgin aggregate to permit higher new binder contents. Another option would be not to recycle at all!

Hot Recycling

A. Sampling

Samples representing the pavement to be recycled are obtained and tested to determine asphalt content, asphalt hardness, and aggregate gradation. The extracted aggregate gradation will influence the selection of the virgin aggregate gradation. It is essential that the final recycled product have a smooth grading curve as would be obtained for conventional mix.

The properties of the recovered old asphalt (removed by the Abson recovery process) influence the grade of asphalt or recycling agent to add to provide a softer final binder.

The material tested must be representative of the mix to be recycled. For example, if the pavement is 1.0' thick but only the top 0.25' is to be recycled, then a pavement core submitted for analysis should only have the top 0.25' considered for a recycling design.

Due to possible variations in the mix of the pavement to be recycled, a large number of samples should be obtained. More than one recycled mix design may be required if the area to be recycled was placed under different contracts or if maintenance overlays had been placed. If more than one design is required, separate stockpiles for each design should be provided. Generally, the differences between old mixes can be tolerated if the mixes are placed in one large stockpile after milling and virgin aggregate is added to the recycled mix to minimize the effect of variations.

B. Recycling Mix Formula

A firm decision on whether to provide a recycled mixture having 100% salvaged or various amounts of salvaged and virgin aggregate should be made during laboratory analysis to provide the best design data to the field. A sudden change in plans concerning the makeup of the recycled mix after a design has been established will result in the delay of construction until a new design is completed. Generally, hot recycling of 100% salvaged AC is difficult due to environmental problems created by burning of the old and/or new binder. To avoid this, the heat transfer system wherein heated virgin aggregate transmits heat to the cold salvaged AC is being employed and mixtures of 60% salvaged, 40% virgin or a 50/50 mix have become popular. Generally, the term heat transfer is applied only to a batch plant which has an upper limit of about 50:50. The drum mixer, while incorporating a system of heat transfer, also provides hot gas to heat the salvaged AC. Thus the formula to use is influenced by such things as amount of AC available, environmental and economic considerations, and in some cases, by the type of plant (batch or dryer drum) available for recycling. For example, a 60/40 mix would be difficult to produce in a batch plant due to the respective volumes involved. In the final analysis, of course, lab tests will verify or indicate the final formula considered workable.

In selecting the gradation of new aggregate to use, such things as the desired final mix gradation and the location of the mix in the structural section (surface, base or level course) are considered.

C. Recycling Agents

The binder added to a recycled mix is in effect considered a recycling agent. This recycling agent could be a soft paving asphalt or a special softening agent that will work to soften the old asphalt. In most cases, the softening agent is preferred although occasionally, if the recovered asphalt is relatively soft (road mixes or a salvaged detour recently placed may be examples), or if small amounts of salvaged AC (20/80 for example) are used, conventional paving asphalts probably should be used. However, assuming a softening agent is selected (it is estimated this will be true in 90% of the cases), the agent with the lowest viscosity will normally have the highest solvating or softening effect. An example of how a grade of recycling agent is selected is presented below:

<u>A 50/50 Recycled Mix</u>

A) Data for recovered old asphalt
   1) Content in mix — 5.2%
   2) Viscosity (cP) — $1x10^7$ (cP)

B) Binder (viscosity AR-2000) demand of virgin aggregate (by Calif. TM 303-CKE Test) — 6.0%

C) Binder required for the salvaged asphalt concrete =

$$\frac{4R + 7S + 12F}{100} \times 1.1 = \qquad 6.1\%$$

<u>where</u>

R = retained #8, %

S = passing #8 retained #200, %

F = passing #200, %

D) Binder to add for a recycled 50/50 mix

1) Salvaged = 100% mix requirement = 6.1%

Asphalt present = <u>5.2%</u>

Additional needed = 0.9%

Amount needed based on a 50/50 mix = $\frac{0.9}{2}$ = .45

2) Virgin aggregate = 100% mix requirement = 6.0

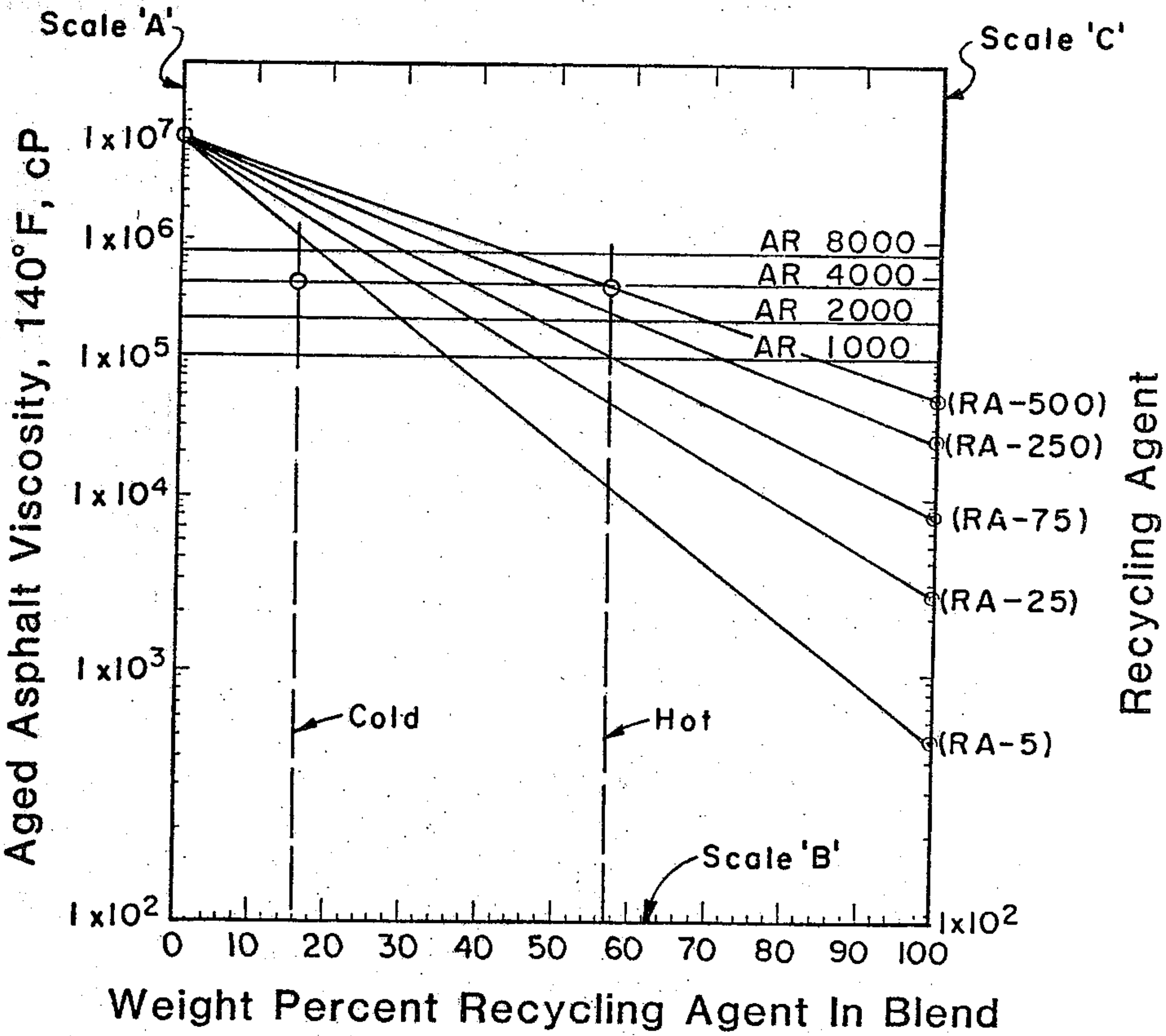
Amount needed based on a 50/50 mix = $\frac{6.0}{2}$ = 3.0

3) Total binder to add = 3.0+0.45=3.45 = 3.5%

4) Total binder in mix = $3.5+(\frac{5.2}{2})$ = 6.1%

E) Total % of recycling agent in the asphalt blend = $\frac{3.5}{6.1}$ = 57.4%

Refer to the nomograph for blending the reclaimed asphalt and recycling agent (Figure 1). 1) On the aged asphalt scale, find the viscosity of the salvaged asphalt (1×10^7); 2) connect a family of curves (straight lines) between this point and the viscosities of the recycling agents; 3) locate on the lower scale (b) the total % of recycling agent in the



NOMOGRAPH FOR VISCOSITY

FIGURE I

blend (57%); 4) construct a vertical line from this point and intersect the horizontal line for the viscosity of asphalt desired (usually AR-4000); 5) select the recycling agent whose viscosity curve is closest to the intersection of the AR-4000 as the grade of recycling agent to try. In the example, an RA-500 would be selected.

D. Final Recommended Binder Content

Caltrans uses the kneading compactor to obtain a compacted test specimen comparable to what would be obtained in the field. The compacted test specimen is tested with the California Stabilometer. The stabilometer test provides stability values ranging from 0-100. The lower end of the scale would represent a highly unstable material and the upper would reflect a highly stable material. We feel that values of 30 or higher should be obtained to avoid the possibility of rutting or bleeding. In order to use as much asphalt as possible (for greater durability), a series of test specimens is prepared with asphalt contents higher and lower than theoretical, i.e., the amount indicated by the blending nomograph (Figure 1). The same temperatures for fabricating and testing as are required for conventional mixtures are used. If the final recommended binder <u>content</u> based on this series varies from the theoretical amount, it is replotted on the nomograph. After being replotted, should the indicated binder be <u>harder</u> or softer than originally planned (AR-4000), a new grade of recycling agent is selected by repeating the selection process and using the newly selected binder content.

Cold Recycling

A. General

Cold recycling can be used under most traffic loadings. However, it does have a tendency to surface ravel under moderate to heavy traffic. Therefore, Caltrans has tentatively elected to include at least a 1" overlay on roadways with moderate to heavy traffic volumes when cold recycling is planned. In our opinion, surface protection for cold recycled, low volume roads, will require only fog seals, slurry seals, or chip seals although this has yet to be verified.

Although occasionally cold recycled mixes may be contaminated with aggregate base during removal, for design purposes they are considered 100% recycled.

B. Sampling

The sampling criteria applied to "Hot" recycling is also required for cold mixes. Thus representative samples of the roadway to be recycled must be obtained. However, because this pavement will more than likely be processed in place, it may be necessary to provide more than one recommendation for binder content. For example, if extensive patching were encountered (200-300' of new mix), this area may require a separate mix design. If so, this area (station to station) must be precisely identified so adjustments during construction may be met. Usually it is virtually impossible to change the grade of recycling agent for short distances. Therefore, the grade used in these areas will be the one selected for the bulk of the project with an adjustment of the amount to be used.

C. Recycling Agents

As with "Hot" recycled mixtures, the binder added to a proposed recycled mix is considered a recycling agent. In cold mixtures, however, the binder most generally is also applied cold. This means, of course, an emulsion of some sort will be used. Due to a lack of heat with this method of recycling, the only part the old asphalt plays in the final mixture is to reduce the absorption of the aggregate and to provide a generally coarser grading (due to coating of the 100 and 200 aggregation fraction). Thus, the old asphalt is a secondary factor unless it can be rejuvenated by softening. We believe the use of recycling agents will provide this rejuvenation. Conventional asphalt emulsions, theoretically, will leave only a very thin film of asphalt residue, which may be insufficient to satisfy the demands of the mixture in terms of long term cohesion. Although it is true that the recycling agent is also emulsified, the residue of the agent will work on the old asphalt and thus provide at least some of it as binder in the new mix. Therefore, Caltrans now favors the use of a recycling agent for cold recycled mixtures although provision will be made for the use of standard emulsions to evaluate their performance in the future.

To select the proper grade of recycling agent, the same nomograph as for "Hot mixes" (Figure 1) is used. The grade selected must obviously be in emulsified form and the emulsion must be assumed to have a residue of 60%. The following page is an example of how the grade of recycling agent and the amount of emulsion are determined.

A 100% Recycled Mix

A) Data from recovered old asphalt

1) Content in mix = 5.2%

2) Viscosity (cP) = 1×10^7 (cP)

B) Binder required for the salvaged asphalt mix =

$$\frac{4R + 7S + 12F}{100} \times 1.1 = \quad 6.1\%$$

where

R = retained #8%

S = passing #8 retained #200%

F = passing #200%

C) Binder to add (emulsion residue):

Binder required = 6.1%

Asphalt present = 5.2

Additional needed = 0.9%

D) Total residual binder in mix = 6.1%

E) Total % of recycling agent in the asphalt blend = $\frac{0.9}{6.1}$ 14.8%

F) Recycling agent to use would be theoretically less than an emulsified RA-5. Therefore, unless it is economically possible to add virgin aggregate to this mix, it should not be considered for recycling unless a softer recycling agent can be provided.

Note: Total emulsion to add $= \frac{\text{Residue }\%}{.60} = \frac{.9}{.60} =$ 1.5%

D. Final Recommended Binder Content

Again, using the California kneading compactor and stabilometer, test specimens are prepared with the selected softening agent in various increments as discussed earlier. The temperature for compacting and testing is 140°F. Studies made of cold mixes indicate that this temperature (tentatively adopted by Caltrans) will provide laboratory test specimens only slightly denser than actual field compaction. The amount of liquid required to achieve maximum compaction in the field with a given compactive effort should not vary considerably if each mix consists of all salvaged AC. This is due to the relatively nonabsorptive qualities of the salvaged AC due to the coating of old asphalt on the aggregate and the gradation uniformity provided by milling or crushing. However, if base contamination occurs, variations in total liquid content in the field may be mandatory. This is very important from the standpoint of the final design recommendation. Such things as surface flushing or bleeding and stability are a function of density. Therefore, the stable mix with no flushing recommended by the lab presumes a field density less than that obtained in the laboratory equal. After the final recommendation for binder content is made, the amount is again checked through the viscosity nomograph. The criteria used for recycling agent grade adjustment is the same as that used for "Hot" mixtures. In any situation where the stability requirement is not satisfied, the grade must be changed and the material retested with various amounts until an acceptable design can be attained.

Summary

There is no question that as we continue to recycle, the design criteria will be modified and adjusted, however, we now seem to be enjoying a fair amount of success.

Our work to date has been rewarding from the standpoint of cost, conservation and service, and we intend to increase our recycling activity into a routine rehabilitation program.

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ASPHALT RECYCLING

QUALITY CONTROL

Presented at

Asphalt Concrete Recycling Seminar

Sponsored by

FHWA and CALTRANS

Sacramento, Calif. - Woodlake Quality Inn - Sept. 15 & 16, 1981

Long Beach, Calif. - Cal. State Univ. Long Beach - Sept. 17 & 18, 1981

Richard C. Ingberg

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Specifications and Quality Control for Hot-Mix Recycling in Minnesota

This paper discusses the work done by the Minnesota Department of Transportation in the last several years to develop specifications designed specifically for the maximum use of salvageable materials in the rehabilitation of pavements. It describes the steps leading to recent specifications for hot-mix recycling, the benefits derived, and the anticipated future of such projects. It also lists the problems involved with these specifications because of the general lack of historical information on projects involving recycling and/or rehabilitation. This report also presents information on Mn/DOT's sulfur extended asphalt projects including a sulfur extended asphalt-recycled project. Other areas touched on are; removal, processing, storage and ownership of salvaged materials; different types of specifications; how to write new specifications; and the development of new specifications. The report contends that the design of a specification is so crucial that the very life of the concept (in this case, recycling and/or rehabilitation) may depend on it. One of the final conclusions is that the proper specification can lead to substantial savings. An example is offered where a savings of about 35% was experienced because a contractor was given the option of two specifications.

It is in the public interest for engineers, material suppliers and contractors to conserve resources such as aggregates and asphalt cement so that maximum use may be attained from the available supply. A large source of this supply has been processed and placed in our present pavement structures. Their usefulness as a pavement structure has deteriorated to the point that vehicle operating costs and pavement maintenance costs have increased so that the pavement is no longer efficiently serving its intended purpose. Sound conservation practices demand that we design specifications to allow the maximum use of these salvageable materials to rehabilitate our pavements as long as their use is compatible with engineering and economic considerations. This paper will discuss some of the experiences in Minnesota to maximize the benefits of recycling salvageable materials. Most of our experience has been with hot-mix recycling. The design of recycling and rehabilitation specifications is crucial to whether or not the recycling of salvageable materials will be economical or even be accomplished at all. Our experience has shown that good specifications result when the interests of the user agency and the contracting industry are integrated and harmonized to produce maximum benefits.

HOT-MIX RECYCLING IN MINNESOTA (PRODUCTION & PREDICTION BY YEAR)

		Actual	Predicted (1977)
1976		20,000	
1977		50,000	
1978		300,000	250,000
1979		60,000	450,000
1980		150,000	600,000
1981	2/81:	600,000 (Est.)	900,000
	4/81:	1,500,000 (Est.)	
	8/81:	2,800,000 (Est.)	
1982			1,350,000

In 1977, we predicted the tonnage of recycled hot-mix that would be produced from 1978 through 1982. As you can see from the chart the growth in recycling has been erratic. The estimate for this year is based on all state and FAS projects with plant-mixed bituminous mixtures that will be recycled mixtures.

The 1981 estimate does not include other public and private work. One of our rural Minnesota contractors estimates that of the 400,000 tons of hot-mix they have under contract 75% or 300,000 tons will be recycled mix. We feel that the adoption of the permissible recycling specifications on all state projects is responsible for the increase in hot-mix recycling in Minnesota.

Experience with Hot-Mix Recycling

Maplewood-Urban
1976 20,000 Tons 50-50; 40-60 Blends Batch Plant

Minnesota's first hot-mix recycling project was constructed in Maplewood, Minnesota, in 1976. (1, 2, 3) This is the project that gave birth to the heat transfer concept of hot mix recycling. The existing aggregate base and asphalt pavement were processed into recycled base and binder courses. The major specification modifications were to process the salvaged asphalt material to a size smaller than 1½ inches, a provision that the salvaged asphalt mixture would not have to go through the dryer, and the temperature of the clean aggregate in the dryer could exceed the standard specification maximum. We learned that with the addition of 120-150 penetration virgin asphalt cement the penetration of the recovered asphalt cement from the recycled mixtures (new and old) was approximately equal to the penetration obtained by the thin film oven test of the virgin asphalt cement. We also found, in this case, that it was not cost effective to haul salvaged aggregate base material long distances back to the hot-mix plant site due to the low cost of new aggregate material. We were extremely pleased at the minimal cost for modification, the quality of the recycled mixture and the ease of laydown and compaction operations.

Fergus Falls-Rural
1977 50,000 Tons 50-50; 60-40 Blends Drum

The following year, 1977, we reconstructed asphalt shoulders on Interstate 094 near Fergus Falls. (2, 4, 5) This was our first rural project and our first dryer drum recycling project accomplished using the heat transfer concept. The salvaged asphalt material was fed into discharge end of the drum with a slat conveyor. We recycled a blend of salvaged asphalt and salvaged aggregate material from 50-50 to 60-40 without excessive opacity at an acceptable production rate of 300 tons per hour. Although we were able to recycle the salvageable materials in the dryer drum, a continuous mix pug mill was placed between the drum discharge and the storage tower in case the drum concept did not work. As the penetration of the old asphalt shoulder was very low (avg. 20) we experimented with adding 200-300 penetration asphalt cement in lieu of the 120-150 penetration asphalt cement we normally use. Even then, we had lower penetration on the extracted asphalt of the recycled mixture than we had anticipated. We believe the lower penetration possibly was due to the recycled material passing through the continuous mix pug mill. We were satisfied with the mixture quality and pleased that the heat transfer concept was successful in a dryer drum plant.

Litchfield
1978 100,000 Tons 60-40 Blend Drum

In 1978, we recycled the old bituminous pavement and shoulders on a large rural project between Litchfield and Atwater, on T.H. 12 (2, 6). On this project we did not specify the size of salvaged asphalt materials entering the drum mix plant. We did specify that the recycled mixture must pass the 2" sieve or one half of the course thickness when deposited into the truck at the plant site. All salvaged asphalt material was processed by dozers running over the stockpile and the use of scalping screens. The contractor would not use this method again due to the cost involved. The recycled mixture was produced at a 60-40 blend of salvaged bituminous material to virgin aggregate at an average production rate of over 450 tons per hour. The salvaged asphalt material entered the drum at the mid-point (center feed). All existing aggregate base was left in place in the roadbed. Base, binder and shoulder wearing courses were constructed with salvaged asphalt material and new virgin aggregate.

Additional Projects 1978
200,000 Tons 60-40; 50-50; 25-75 Blends

The above project was only one of several hot-mix recycling projects in Minnesota in 1978. We were encouraged by the variety of these projects, two state projects, two city projects, and two airport projects. We thought we were on our way with recycling in Minnesota. What we didn't realize was the amount of effort we were spending lining up specific projects for recycling. We also were unaware that recycling would fall off considerably in 1979.

Projects 1979 60,000 Tons

1979 was a disappointment for hot-mix recycling in Minnesota. We had very limited tonnage. We were using a permissible specification for recycling on several projects, however, no contractors were producing recycled mixtures on these projects. Because of this, we modified our specifications to pay for the old asphalt in the recycled mixture.

Projects 1980 150,000 Tons
30-70; 40-60; 50-50; 60-40; 70-30 Blends

This year, 1980, Specification 2332 (7) permissible hot-mix recycling produced recycled mix on several projects. We have a large airport runway project, an interstate project, and two trunk highway projects. We have turned the corner in hot-mix recycling. Every contractor has the incentive to look at every project and weigh the costs and benefits of recycling vs. concentional mixtures. This specification is a part of all Mn/DOT projects (8). No longer do we have to specify hot-mix recycling for specific projects. The contractor decides when and how to recycle and bids accordingly. We recently let a project which included the revised permissible hot-mix recycling specification. The contractors bid for the recycled hot-mix portion of the project including mobilization was $547,163.03 compared to the engineers estimate based on conventional construction, of $837,970.85 for the same items. This represents a savings of approximately 35%. The first two bidders bid $65.00 and $66.00 per ton for asphalt cement compared to the engineer's estimate of $163.50/ton.

Experience with Sulphur Extended Asphalt and Sulphur Extended Asphalt-Recycled

1979 was a year we forgot about hot-mix recycling. We experimented with two sulphur extended asphalt projects (9). One was a rural project incorporating approximately 44% sulphur to 56% asphalt cement by weight as binder. Gulf Canada provided the blending equipment and expertise. We were pleased with the results. The other project was a sulphur extended asphalt recycled, with salvaged asphalt material as a component as the paving mixture along with sulphur and new asphalt cement. Sulphur Development Institute of Canada provided the blending equipment and expertise. This project assured us that we could combine sulphur with recycled salvaged asphalt material without any problems.

Salvaged Materials

Source of Salvaged Material for Reuse

Where does the material come from to produce recycled pavements? Unless a contractor owns an aggregate supply or some other structure containing reclaimable materials, his source of reclaimed material must be provided by private industry or public agencies. A point to keep in mind is that it is not important where materials are obtained for producing paving mixtures. The quality and gradation of these materials is important as this will determine how they will perform in the pavement structure. Urban projects will differ from rural projects (10). Most of these materials will be derived from existing pavement structures. On large rural projects, the characteristics of these materials can be determined prior to design and construction and will in most cases, be salvaged and recycled into the new pavement structure. On urban projects, due to their relatively small size, the materials removed from the project cannot easily be recycled and returned to the same project. Therefore, on urban projects, the quality of the material will be determined from the previously stockpiled material from many and varied sources. However, keep in mind that the characteristics of the materials incorporated into the paving mixture are the important aspects to be concerned about.

Storage and Ownership of Salvaged Material

The entity responsible for producing the recycled mixture should be responsible for the removal, processing and recycling of these materials. For example, some user agencies have specified removal and stockpiling of asphalt pavement structure as a part of a separate grading contract. <u>One of the basic problems in doing this is the lack of interest in retaining the inherent quality of the pavement removed and stockpiled</u>. Experience has shown that deleterious and objectionable material have contaminated the stockpile thereby insuring an inferior recycled mixture with a large potential for premature failure of the recycled pavement structure. It also has allowed time for moisture contents to build up in the stockpile thus requiring fuel for drying, making pollution control more difficult, and reducing the rate of plant production of recycled mixtures. This adds unnecessary expense to the user. A simple way to eliminate this unnecessary expense is to make the removal, processing and stockpiling of salvaged material the responsibility of the persons producing the recycled mixture. Contractors who have this responsibility have the incentive to carefully remove, process, and stockpile these materials and keep costs to a minimum. This year contractors in Minnesota cover or construct their salvaged asphalt material stockpiles to prevent or reduce moisture buildup. With the price of liquid fuel near $1.00/gallon each 5% of moisture per ton of mixture will require $1.00 per ton to remove the moisture. Many unprotected stockpiles have moisture contents ranging from 5-15%. The user agency should not retain the ownership of salvaged materials unless they are willing to protect its quality. Ownership should go to the person controlling the end use of the material.

Pay for Removal of Salvageable Material

The user agency should pay for the removal of materials on a project. These materials will then become the property of the contractor to dispose of as he sees fit. This is what we have been doing with materials removed from all our projects in the past. The only difference was that most of these materials were being hauled to a landfill for disposal or disposed of within the right of way and not used in the pavement structure.

Establish Value for Salvaged Material

The user agency should allow the contractor to incorporate these potentially valuable materials into recycled mixtures for payment equal to conventional mixtures. In other words, these salvaged materials would continue to be hauled to landfills unless we were willing to use and pay for the recycled mixtures that could be produced from these materials.

By allowing the use and payment for salvageable materials in lieu of conventional materials, the user has established value for salvageable material. Unless this is done, salvageable materials will either be hauled to a landfill or as some enterprising contractors are doing, they will be incorporated into recycled asphalt mixtures for the private market sector.

Salvaged material has no value until the user is willing to accept it as part of a recycled pavement.

Development of Permissible Hot-Mix Recycling Specifications

The first step in developing specifications for recycling were the special provisions used for the Maplewood project. We used the maximum size requirements from other recycling projects. We designated the thickness of aggregate base to be salvaged. The gradation of the salvaged aggregate was required to be reasonably uniform from fine to coarse with 100% passing the 1½" sieve. The gradation of the processed salvaged bituminous material was required to have a reasonably uniform gradation from fine to coarse with 100% of the material passing the 1½" sieve.

The salvaged materials were measured and paid for by the ton. They were to be placed in separate stockpiles. We also allowed up to 20% salvaged aggregate to be incorporated into the salvaged bituminous to facilitate crushing or processing.

The standard plant mixed bituminous pavement specifications were modified as follows:

1. The contractor was required to submit an acceptable proposal for preventing or eliminating excess air pollutants.

2. A means for adding the salvaged bituminous material to the heated aggregate after the aggregate has left the dryer. Also positive control on proportioning the salvaged material into the mixture.

3. When adding salvaged bituminous mixture for the bituminous base and binder courses it may not be necessary to run the salvaged bituminous material through the dryer.

4. We gave the approximate mixture proportions which ranged from 20-40%, for salvaged bituminous and 60-80% for the salvaged aggregate.

5. Aggregate leaving the dryer could be heated in excess of 325 degrees F.

6. Costs for equipment modification at a lump sum bid not to exceed $15,000. Also required was the itemized cost for modification.

7. Payment similar to conventional mixtures except there was no payment for old asphalt cement in the salvaged bituminous material.

Our first change to the above special provisions occurred in 1978 when we deleted the 1½" maximum size in the salvaged bituminous material. The maximum size requirement applied to the recycled mixture after being processed through the hot-mix plant and deposited into the transport vehicle.

Up to this point in time almost all our projects had been specifically designed for recycling. If recycling was ever going to reach its potential, we had to provide a permissible specification for allowing recycled mixtures in lieu of conventional mixtures on all projects. We also were spending too much engineering time setting up projects for recycling without really knowing for sure, in some cases, whether recycling was cost effective.

Therefore, in 1978, we began the development of a permissible hot mix recycling specification to allow the contractor to use recycled mix in lieu of conventional mix. As a part of this specification, we made several significant changes. The most important change was to establish mix design criteria for recycled mixtures which are discussed later in the actual specification, 2332.

Another change was establishing a job-mix formula if virgin aggregate was used in recycled wearing course mixtures. The requirements are the same as those required for conventional wearing course mixture. The job-mix formula applies only to the virgin aggregate portion of the recycled wearing course mixtures. The virgin aggregate portions of recycled base and binder courses must meet the broad gradation bands similar to conventional base and binder course mixtures. We do not design mixes for conventional base and binder mixtures.

This specification was included in many projects to be let in 1979. However, contractors were not using the specification, therefore, the volume of hot-mix recycling did not meet our growth expectations. It did not take long to realize that the way our pay items are set up in Minnesota, if we were to continue not paying for the old asphalt cement in our recycled mixtures there would be little, if any, recycling.

This led to our most important and controversial change in our specifications, paying for the old asphalt in the salvaged bituminous material. Several engineers in Mn/DOT did not agree with the philosophy of paying for asphalt cement we already owned. However, the free market mechanism compensates for this in the competition bidding process.

An explanation of why it is necessary to pay for old asphalt cement is best accomplished by the following example:

Assume a project requires:

Asphalt Cement	1,000 ton at $200-/ton	$200,000
Bituminous Mixture	20,000 ton at $10-/ton	$200,000
	Total Bid	$400,000

Assume salvageable asphalt pavement is available for a 50-50 blend recycled mixture with an asphalt content equal to that of a new conventional bituminous mixture. The recycled mixture would require only half of the asphalt cement required for conventional mixture.

Therefore, if the contractor decided to recycle, his payment for the recycled product would be as follows:

Asphalt Cement	500 tons @ $200-/ton	$100,000
Bituminous Mixture	20,000 tons @ $10-/ton	$200,000
	Total Payment	$300,000

Now, no contractor in his right mind would bid the job for $400,000 and then decide to recycle and obtain only $300,000 payment for his work. He would furnish us with conventional asphalt pavement and salvage the old pavement and recycle it for someone else who was willing to pay him conventional mixture price for the recycled mixture.

We solved this problem by paying for the new asphalt and the old asphalt in the final recycled mixture. This allows all bidders to establish a value for salvageable pavement materials he intends to incorporate into recycled mixture on the project. The contractor will reduce his price for asphalt cement or for the type or course of mixture in his bid proposal to reflect this value.

This has been the key to establishing hot-mix recycling in Minnesota as a standard operating procedure. In 1979, we had one supplemental agreement where a contractor used the new specifications. In 1980, the permissible specifications were being used on all projects (7, 12).

Selection of Alternative Recycling and Rehabilitation Procedures

When writing specifications for recycling and rehabilitation procedures, keep in mind who is best able to make the decisions that will maximize the benefits of recycling and rehabilitation procedures. The designer and the staff specialists such as the bituminous engineer, materials engineers, research engineers, planners,etc., have a very important role to play in determining the present condition of the pavement and what the pavement will be expected to provide in the future. A very important factor today is the lack of funds to most cost effectively provide an acceptable transportation system. Funding levels will have a heavy impact on the best available solutions which will provide the most appropriate level of service to the public. Another problem facing us is the lack of a defensible service life of various rehabilitation procedures. In absence of long term evaluation for durability a best estimate of service life must be determined. This is best accomplished by a team of experts. From this best estimate future modification to the estimate will be forthcoming as time and testing provide more precise answers to service life. We are beginning the process of establishing service lives for recycling and rehabilitation procedures in Minnesota. The Federal Highway Administration is also establishing a data bank on recycling projects. This should help guide us in the future.

Method vs. End Result Specifications

There are basically two types of specifications. Method specifications, which specify exactly how to do the work, what equipment to use, how to use it, and to some extent, what the end result should be. End result specifications leaves it up to the contractor to provide the end result without instructing him how to produce the end result.

The most practical specification is a combination of method and end result specifications that combines the expertise of the user agency, contractors, material suppliers and equipment manufacturers to produce a good end product almost all of the time at a reasonable cost.

Energy

The engineer need not concern himself with the energy saved or consumed for any design alternative provided the cost of energy is reflected by free market condition and so long as the specifications permit realistic alternatives to the bidders.

Development of Specifications

As you can see, the thrust in Minnesota is to develop permissible recycling specifications along with alternative rehabilitation procedures which will allow the contractors as much latitude as possible. However, this cannot be accomplished unless we find a way to make recycling a standard operating procedure. Each user agency must develop their own standard specifications for hot, cold and surface recycling. In most cases, the state user agency should be the leader in establishing these specifications.

The question then becomes, how do we transition from our past practice of almost exclusively building pavements out of new materials to one of utilizing salvaged or reclaimed materials for reconstructing or maintaining our pavements. This is a new and challenging field. More challenging than new design and construction because we have to find new ways of evaluating recycling methods and materials and predicting their future performance. If you thought performance of our old designs were difficult to determine, recycling procedures are infinitely more difficult to predict. However, we have no choice. We have to make intelligent decisions based on past experiences until more definite data is available for modifying our initial performance predictions. The initial answer will be to look at the properties of these salvaged materials in comparison to the materials used in the past. This is what we have done with hot-mix recycling. This is what we are doing with sulfur-extended asphalt mixtures (11). As with any new product or procedure, we measure its properties and performance in relation to what we have done in the past.

We cannot wait another 15-20 years to determine the actual service lives of recycling and rehabilitation procedures. By waiting, millions of tons of potentially reclaimable material will be wasted and forever lost at a tremendous cost to the public. Also keep in mind that recycled pavements can have an added bonus of costing less than our conventional pavements. Another important benefit is less demand for new aggregates and asphalt cement, both non-renewable resources. Another important benefit is that landfills in our urban areas will take longer to fill and reduce the demand for new landfill sites further and further from the source of waste material thus reducing the cost of transportation.

Each area of the country must start with the specifications they are now using and begin to modify them by comparison with the practices of a number of experienced agencies as expressed in their specifications. There are many specifications to study and evaluate when writing your own specifications. Your specialists responsible for writing your specifications know your area of the country and are best equipped to modify or create specifications that will fit your area. In addition, you should involve the contracting industry to assist and help you write specifications that will allow the free market mechanism to work. There should be as many alternatives as possible to allow maximum competition which will produce the desired product at the least cost.

Rehabilitation of a deteriorated pavement should not be undertaken until a complete and thorough investigation has definitely established the cause of the failure. Next the most feasible and economical measures to correct the deficiencies must be determined. Alternative designs for rehabilitation should take into account the potential salvageable pavement materials that could be used.

The plans, specifications and special provisions should provide this information. The contractors bidding the job have the knowledge of what materials are available and all optional designs. With this information, he can use his expertise and know-how to determine how these materials can be processed most economically to provide the desired end result.

RECYCLED PLANT MIXED BITUMINOUS PAVEMENT

SPECIFICATION 2332

Background.

The specifications for Recycled Plant Mixed Bituminous Pavement are based on (Minnesota Department of Transportation Standard Specifications for Highway Construction, 1978 Edition) specification 2331, Plant Mixed Bituminous Pavement. Specification 2332, Recycled Plant Mixed Bituminous Pavement, allows the contractor to substitute recycled mixtures in lieu of conventional specification 2331, Plant Mixed Bituminous Pavement, provided, the provisions of 2332 are met. We have chosen this method to produce an acceptable pavement at the lowest possible cost. It allows the contractor to choose materials for producing the pavement mixture based on the cost of materials at the time of production. The blend or properties of salvaged asphalt materials to virgin aggregate is selected by the contractor provided the recycled mixture meets the specification requirements. Pay items for the materials incorporated into the work are the same for each course or type of mixture. The contractor could produce conventional or recycled asphalt pavements on the same project provided that compliance with each of the specifications are met.

Summary of Specification 2332

Recycled Plant Mixed Bituminous Pavement

2332.1 Description.

This work shall consist of constructing one or more pavement courses of hot plant-mixed bituminous mixture on a prepared grade or subgrade using a combination of virgin and/or salvaged material.

2332.2 Materials.

Aggregate.

Salvaged aggregate materials to meet Specification 3139 for composition (3139.2A), running average passing No. 10 ± 8(3139.2B), L.A. loss (3139.2D) less than 40%, Spall Materials (3139.2E) to meet BA-2 for all courses except BA-3 for base courses. Gradation - coarse to fine, 100% passing 1½" sieve. No gradation limits required.

Virgin aggregate material to meet 3139. Sampling and testing of virgin and salvaged aggregate to meet 3139.3.

Salvaged Bituminous Material processed to provide uniform gradation from coarse to fine.

Processing of all materials incorporated into our recycled mixture to assure that the final recycled mixture(s) as loaded into transport vehicles at the plant shall be:

100% passing 2" sieve, or

100% passing lift thickness divided by two, whichever is less.

For 1" courses: 100% passing the 3/4" sieve.

Bituminous mixture containing road tar not permitted. Salvaged bituminous pavement and salvaged aggregate shall be free of objectionable matter and materials.

Bituminous Materials.

SC Liquid Asphalt	SC-3000
Asphalt Cement	85/100, 120/150, or 200/300 Pen.

The Engineer may approve or require the addition of mixing or coating aids or softening agents.

2332.3 Construction Requirements.

Equipment.

Processing of all materials through the dryer will not be required.

Mixture Proportions.

The Contractor shall maintain the amount of new AC added within $\pm 0.3\%$ of the amount specified by the Bituminous Engineer.

At least 15 days prior to the production of recycled mixtures, the Contractor shall submit the following to the Bituminous Engineer:

1. Representative samples of each material (300 lbs. each).
2. Production results for each material:

   Gradation of virgin aggregate.
   Extraction results for salvaged bituminous material.
3. Proposed proportions or blend of materials.

Using the above information, trial mix tests will be run to determine percent of new asphalt cement to be added.

Trial Mix Criteria:

Marshall Stability: 500-3000 lbs.

Voids in Mix:	Non-wear	4-8%
	Wear	4-6%
Cold Water Abrasion Loss:	Non-Wear	15% Max.
	Wear	10% Max.

After the Trial Mix Testing has been completed, the Bituminous Engineer's recommendation will establish the amount of new asphalt required and the material proportions. The percentage of added asphalt and the proportions of the other materials used in making that determination shall remain in effect until modified in writing.

No recycled bituminous mixture shall be produced until the amount of new asphalt added and material proportions have been established by the Bituminous Engineer.

Percent of salvaged bituminous material in recycled mixture not to exceed 70% by weight.

The Job Mix Formula for wearing course mixtures establishes a single percentage point for virgin aggregate passing each sieve. The tolerance for the single percentage point on each sieve is:

Virgin aggregate passing #10 & larger sieves....±8%

Virgin aggregate passing #40 sieve..............±7%

Virgin aggregate passing #200 sieve.............±3%

A new Job-Mix formula is required for change in source(s) of aggregate(s) or change in proportions of materials.

Bituminous Mixture.

Control and acceptance of asphalt content in final accepted recycled mixture:

The Contractor is responsible for quality control of the proportions required during recycled mixture production.

Asphalt content of the final recycled mixture is determined for each mixture by the State.

Samples will be taken from the uncompacted mat in each lift, directly behind paver, for each course of production.

Sampling rate: 1/750 tons, Min. 3 per Course.

Samples will be taken from randomly selected locations.

Extraction test to determine asphalt content will be by Colorado Vacuum Extraction apparatus using procedure AASHTO T-164-76 Method E (ASTM D.2172-67).

Average of asphalt content, without retention factor, for each course will determine payment for asphalt cement (new and old) under item 2331.504 Bituminous Material for Mixture.

Plant Operations.

Different materials will be kept in separate stockpiles and placed into the mix without segregation.

The aggregate in the dryer may exceed 325 degrees F.

2332.4 Method of Measurement.

A. Bituminous Mixture

Recycled bituminous mixture of each type will be measured separately by weight, based on the weights of loads hauled from the mixing plant, with no deductions made for the bituminous materials incorporated therein.

B. Bituminous Material (Asphalt Cement)

The total amount of bituminous material (asphalt cement, new and old) in the final recycled mixture will be measured by weight (extraction) in all recycled mixtures.

2332.5 Basis of Payment

Payment will be made for accepted quantities of recycled bituminous mixture used in each course at the contract price per ton for <u>bituminous mixture</u>.

Payment will be made for new bituminous material and the old residual bituminous material incorporated in each recycled mixture at the contract price per ton for <u>Bituminous Material for Mixture</u> (Asphalt Cement).

This shall be compensation in full for all costs of constructing the recycled bituminous surfacing as specified.

Payment for the recycled plant-mixed bituminous surface (Specification 2332) will be made with the same schedule as conventional mixture (Specification 2331) items:

Item No.	Item	Unit
2331.504	Bituminous Material for Mixture..........	Ton
2331.508	Wearing Course Mixture..................	Ton
2331.510	Binder Course Mixture...................	Ton
2331.512	Leveling Course Mixture.................	Ton
2331.514	Base Course Mixture.....................	Ton
2331.516	Shoulder Mixture........................	Ton
2331.518	Bituminous Mixture for Specified Purpose.	Ton
2331.531	Temporary Lane Marking..........	Road Station
2331.549	Bituminous Mixture Production...........	Ton

NOTE: If either mineral filler or hydrated lime is to be required in any bituminous mixture Item, the Item Name must be expanded by adding the words: (with Filler) or (with Lime).

EDUCATION AND TRAINING

Information on recycling needs to be communicated to the persons designing, controlling and constructing streets and highways.

The latest technical information on the state of the art of recycling has been provided to consulting firms, the contracting industry and public agencies through annual seminars such as Bituminous Conference, American Public Works Association Workshops, Bituminous Superintendents Workshops and District Seminars on Evaluation, Design and Construction.

St. Paul Technical Vocation Institute in cooperation with the Minnesota Department of Transportation and the Minnesota Asphalt Pavement Association offers a Construction Technician Training Program. Courses are designed to give individuals engaged in highway construction and materials testing the latest technical information and the fundamental principles involved in the design, construction, and quality control procedures. Courses have been given in each of the construction districts for individuals working for public agencies, consulting engineers and contractors.

Richard O. Wolters, P.E., Mn/DOT Bituminous Engineer, was the instructor for Bituminous Technology I and II, 36 hours for each course or 72 total hours. Bituminous Technology I covers bituminous materials and mixtures including properties of asphalt, mix design parameters and construction specifications, plants, recycling, placement and control procedures. Bituminous Technology II is a laboratory course involving hands-on-work testing of bituminous materials and mixtures. Individuals taking these courses have been evenly divided between contractor personnel and technicians from consultants, city, and county and state agencies.

The Minnesota Local Road Research Board is sponsoring a slide tape presentation on Recycling under Investigation 645 "Implementation of Research Findings". This should be completed in 1982.

QUALITY CONTROL

Quality of a recycled mixture depends on the salvageable materials available and how the contractor combines the salvageable and new materials to produce a recycled mixture. Our recycling specification gives the contractor the responsibility to produce the recycled mixture at whatever blends he decides to use provided he meets mix design and specification criteria.

Quality control begins with the salvageable materials available for the project. In an urban area, much of this is determined by the materials the contractor has stockpiled. Some contractors segregate materials as to asphalt content and gradation. Information from as-built records of the layers or courses removed from a project and laboratory testing can give the contractor information so he can determine how to obtain the best end use of this material. There will be salvageable asphalt material from many and varied sources which may be blended and then tested to determine their characteristics. Normally this material will be used in recycled base mixtures or as a substitute for aggregate base. The contractor will control the re-use of these materials to meet the demands of the market in his area.

QUALITY CONTROL FOR URBAN RECYCLING

Urban recycling is different than recycling in Rural Areas. On rural projects, recycling is usually planned in advance and the owner-agency has plenty of time to test the inplace material for asphalt content and gradation and can arrange the design to accommodate for the mixes characteristics.

However, in the urban area, recycling is almost always at the contractors option and seldom is salvaged mix from a given project used in recycled mix back on that project. Also, mixes in urban areas can vary to a greater degree; from oil dirt streets to high type asphalt concrete and from asphalt treated bases to high asphalt content wearing courses. The quantities of material salvaged from any specific job also varies considerably from a truck load of salvaged material, from a sewer repair project to many 1000's of tons on a street reconstruction project.

Under the permissible specification, the quality control for recycled mix is the contractors problem. It is impossible to have quality control of a mix being produced without adequate control of the raw materials; this control involves the following items:

1) Evaluation of the proper method of removal. The type and quality of material inplace as well as the inplace thicknesses and depth of removal must be considered when deciding whether to rip and crush or mill. Also, the quality of aggregate and asphalt content of various inplace layers should be considered when determining the depth to be milled by each pass.

2) Stockpiling control - care must be taken when stockpiling not to mix material of various qualities and/or AC content.

3) Testing must be performed on the salvaged materials to determine the asphalt content and/or gradation of the salvaged materials. These test results are used for segregating the materials in stockpiling for storage as well as for determining proportioning of slavage to virgin aggregate and percent of virgin asphalt added to produce the recycled mix. (See Total Asphalt Construction's Example after Problem Statements.)

4) Plant calibration - unless proportioning is by weight, the plant feed must be calibrated to assure accurate proportioning during production of recycled mixes. (See Total Asphalt Construction's Plant Calibration after Testing Example.)

5) Quality assurance - testing to determine the asphalt content of the salvaged material going into the plant and the asphalt content and gradation of the recycled mix coming out must be done on a continuing basis to assure that a quality mix is being produced.

Problems

The standard procedures used to determine asphalt content and gradation in conventional mixtures do not completely meet the needs for a contractors quality program with recycled mixes.

1. Because of the variability in salvaged materials, caused both by the nature of the material, and the size variations involved and the fact that salvaged material can be and usually is a mixture of treated and untreated materials, as big a sample as possible is desirable. The Colorado Vacuum extractor best fits this requirement of the tests now available.

2. Speed is an important factor in determining asphalt content. With the vacuum extractor, the actual extraction time can vary from 1 hour to 7 hours. In addition 1 to 4 hours drying time is required before and after extracting.

3. To speed the extracting process, a filter aid (celite) is used which coats the filter paper to prevent clogging of the filter. This speeds the extracting process but adds 30 to 50 grams of material to the aggregate residue which makes the resultant gradation questionable.

4. The oil residue on the aggregate after extraction affects the wetting action during the washing portion of the gradation. An additive can be used to overcome this problem, but introduces another variable in the results.

5. The time to run a gradation on the extracted aggregate can be substantial - overnight soaking is routine, 1 hour to wash thru a 200 screen, 1 to 4 hours to dry - 1 hour to run screen test.

6. The use of salvaged materials for granular base presents real problems for testing by correctional testing. When the salvage contains asphalt, care must be taken as to the method of drying as heating the mixture above a certain temperature will cause a change in gradation. For a given sample, whether the sample is oven dryed or burner dryed between washing can cause the minus #200 sieve content to vary by a factor of two.

For example, summaries of the extraction and gradation tests run by "Midwest Pavement Management, Inc. (MPM, Inc.)" for Total Asphalt Construction Co. are as follows:

Total Asphalt Inc.

Extraction Results

Hot-Mix #	Hot-Mix A.C. Content	Date Sampled	Salvage #	Salvage A.C. Content
1	) Oven)-Problems	7/1	1	3.1
2	) (5.4%)?	7/2	2	2.9
3	5.41	7/8	3	3.6
*4	4.91	7/10	4	3.54
5	5.00	7/14		
C1-5	0.85	7/8		

* -- Sent to Mn/DOT Lab. for comparison.

Total Asphalt Inc.

Extraction Results

% Asphalt Added to Recycled Mix	Date Sampled	Hot Mix			Salvage			Sample From Bin		
		#	% AC	% Mois	#	% AC	% Mois	#	% AC	% Mois
--	7/20	6	4.6	---	6	4.3	2.25	1	0.8	0.2
--	7/22	7	4.9	0.0	7	4.0	---	2	0.6	0.2
--	---	8	4.5	0.3	8	3.6	2.9			
--	7/30	9	3.9	---	9	3.9	2.7			
--	8/3	10	4.0	---	10	3.74	3.1			
2.5%	8/6	11	4.0	0.1	11	6.1	2.1	3	0.9	0.14
3%	8/10	12	4.0	0.3	12	3.6	2.9	4	0.8	.33
3%	8/12	13	4.4	0.1	13	3.8	2.4	5	0.8	.2
3%	8/18	14	5.1	0	14	5.0	3.3	6	2.0	.15
3%	8/19	15	5.3	0.6	15	3.4	2.7	7	1.4	.32
4%	8/20	16	5.5	0.2	16	4.0	3.3	8	.82	.37

GRADATION

Sieve Size	Salvage 3	Hot-Mix 3
1"	100	100
3/4	99.4	98.8
5/8		
3/8	83.5	82.9
4	70.7	71.5
10	55.1	58.5
40	28.0	30.5
200	9.7	8.1

The foregoing test results indicate excellent uniformity and bitumen contents and are within design tolerances.

TOTAL ASPHALT CONSTRUCTION COMPANY

PLANT CALIBRATION

Virgin Aggregate Cold Feed

Belt Speed

Bottom Pulley - 9-3/4" diameter, 31" circumference

$$126 \text{ rev/min.} \times 31\text{"/rev.} \times \frac{1 \text{ foot}}{12 \text{ inches}} = 325.5 \text{ ft./min.}$$

Aggregate Feed Calibration (no sand)

Dial Setting	Wet Weight*	Dry Weight*	Dry Weight #/Ft.	Dry Weight Tons/Hr.
30	80.4	78.15	13.03	127.24
35	96.6	93.9	15.65	152.82
40	106.5	103.5	17.25	168.45

*For six-foot section of belt.

$$\text{Moisture Content} = \frac{619.9 - 603.0}{603.0} = 2.8\%$$

Salvage Feed Calibration

Belt Speed = 4'/sec. or 240'/min.

Salvage Feed = 150.1# in 40' wet.

$$\text{Mic.} = \frac{639.7 - 607.0}{607.0} = 5.4\%$$

$$\text{Feed Rate} = \frac{150.1 \times (1-.054)}{40} \times 240 \times \frac{1 \text{ Ton}}{2000\#} \times \frac{60}{1} = 25.6 \text{ T/Hr.}$$

PLANT CALIBRATION

For Salvage Feed = 25.56 T/hr.

% Salvage	Total Feed	Virgin Feed	Setting
5	511.2	485.6	
10	255.6	230.04	54
15	170.4	144.84	34
20	127.8	102.24	24
25	102.24	76.68	
30	85.2	59.64	
35			

For Setting = 37, virgin feed rate = 158 T/hr.

$$\% \text{ Salvage} = \frac{25.56}{158 + 25.56} \text{ X } 100 = 13.9\%$$

Assume 6000# Batch
-25.56 T/hr. Salvage Feed, 4% AC in Salvage

Base Design

100% Virgin - 4.5% = 6000 X .045 = 270# AC-1

- Setting 37, 13.9% Salvage:

  (6000# - 270) = 5730# Agg.
  (5730) X .139 = 796# Salvage
  796 X .04 = 32# AC-1
  Virgin AC-1 needed = 270 - 32 = 238#

- Setting 34, 15% Salvage:

  5730 X .15 = 860# Salvage
  860# X .040 = 34# AC-1
  Virgin needed = 270# - 34# = 236#

- Setting 24, 20% Salvage:

  5730 X .20 = 1146# Salvage
  1146# X .04 = 46# AC
  Virgin needed = 270 - 46 = 224#

URBAN VERSUS RURAL

It is helpful to recognize the differences in urban and rural hot-mix recycling. In general, the differences are:

	URBAN	RURAL
Plant Site	Permanent	Portable
Plant Type	Batch or Continuous	Drum Mix
Market Area	Overlapping	Wide & Dispersed
Project	Within Market Area	Plant Site Within or Near Project
Blends	Low Percentage (10-40%)	High Percentage (40-70%)
Durability	Less concern due to lower blends	More concern due to higher blends
Salvaged Materials	Obtained from varied sources, less uniform	Obtained from project - more uniform
Gradation	Easier to correct gradation	Harder to correct gradation
Quantity	Low tonnage/project	High tonnage/project
Savings/ton	Less	More
Market Development	More complex	Project Dictates
Cost Effectiveness	Great potential due to varied sources and markets	Project dictates
Mobilization Costs	None	Substantial ($30,000 plant set up)
Aggregate Cost	More Expensive	Less Expensive
Aggregate Source	Haul to site (not always)	On or near plant site (most cases)

QUALITY CONTROL FOR RURAL RECYCLING

In rural areas, the project itself will be a large determinant in the contractor's selection of re-use of salvageable materials. Additional projects in the area will also control the contractor's decision. Information from the as-built records along with preliminary testing will give the contractor the necessary knowledge to intelligently bid the projects. The information also gives the designer an opportunity to choose alternative rehabilitation designs to allow the contractor the choice of which alternatives will give the most economical end result.

QUALITY CONTROL EXAMPLES

Examples of how we have processed several projects are as follows: (See Appendix A for Project Checklist.)

S.P. 7380-167 T.H. 094
Melrose to Albany
Length: 10.97 Miles
Letting Date: October 26, 1979
Contractor: BAUERLY BROS., INC.
Type of Work: Bituminous Resurfacing and Bituminous Shoulders

This is a rural four-lane Interstate highway. Approximately eight miles required additional structure consisting of 3-3/4 inches of 2331 bituminous base, 1¼ inch 2331 bituminous binder, and 3/4" of 2361 wearing course. The existing 2" shoulders were removed and replaced. The westerly three miles consisted of three experimental test sections. Test section No. 1 called for 1½" removal and replacement with 1½" 2331 binder and 3/4" 2361 wearing course; test section No. 2 called for 3½" removal and replacement with 3½" 2331 binder and 3/4" 2361 wearing course, and test section No. 3 called for 1" heater scarification plus a 3/4" 2361 wearing course.

The contractor elected to recycle the salvaged bituminous material from the shoulder in accordance with Mn/DOT's permissible recycling specification 2332. The information from the trial mix design and pavement are shown below:

SP 7380-167 TH 94

MATERIALS PROPERTIES

	AS BUILT (from plans) 1½" W.	2" B	2" Shldr.	CONTRACTOR'S SAMPLES Prelim. Pav't. Slabs 3½" B + W	2" Shldr.	Milling Stockpiles 1½" W.	3½" B + W
% Asphalt Cement	5.2	4.5	5.8	4.4	5.7	5.4	5.4
Penetration 77°F				29	28	25	22
Viscosity				9470 Poises	10,930 Poises	838 Cs	926 Cs

TRIAL MIX RESULTS

Ratio Salv/Virgin	Mix Type	Asphalt % Added	Cement Pen. Grade	Density (pcf)	Flow (inches)	Stability (lbs.)	Air Voids (% in Mix)	C.W.A. (% Loss)	Salvage Source
0/100	Shoulder	5.3	120/150	145.8	.06	1157	4.6	4.4	
0/100	Base & Binder	4.5	120/150	141.1	.06	553	9.4		
35/65	" " "	3.2	200/300	146.5	.08	1362	5.2		Shoulder
45/55	" " "	2.3	200/300	146.2	.10	2343	6.3	6.9	1½" Milling
45/55	" " "	2.9	200/300	146.3	.09	1888	5.2	7.3	3½" Milling
45/55	" " "	2.6	200/300	147.5	.09	1797	5.0	5.9	Shoulder

EXTRACTION RESULTS

Base & Binder Course	Trial Mix Specimens (n=3) 0/100 at 4.5%	45/55 at 2.3%	45/55 at 2.9%	Field Samples (n=51) Various Ratios
% A.C. Extracted	4.4	4.3	4.8	4.59
Penetration at 77 F	69	40	54	
Kinematic Viscosity (Cs)	312	632	506	

SP 7380-167 TH 94

SIEVE ANALYSIS

	CONTRACTOR'S SAMPLES				TRIAL MIXES			FIELD SAMPLES	
	Pavement Slabs		Millings Stockpiles		Base and Binder				
	Shoulder	Mainline	1½" (3)	3½" (4)	Conv. (5)	45% Millings 1½" (3)	45% Millings 3½" (4)	Bit. Mix (n=51)	Aggregate (2) Stockpile (n=4)
3/4"					100	100	100	100	100
5/8"	100		100	100	99	99	99	98	98
1/2"		100	98	99					
3/8"	91	97	96	96	89	85	87	86	83
#4		74	90	88	74	70	74	71	66
#10	58	54	69	66	56	55	54	52	51
#40	22	26	32	29	18	22	20	18	17
#200	9	10	11	10	4	6	6	6	4

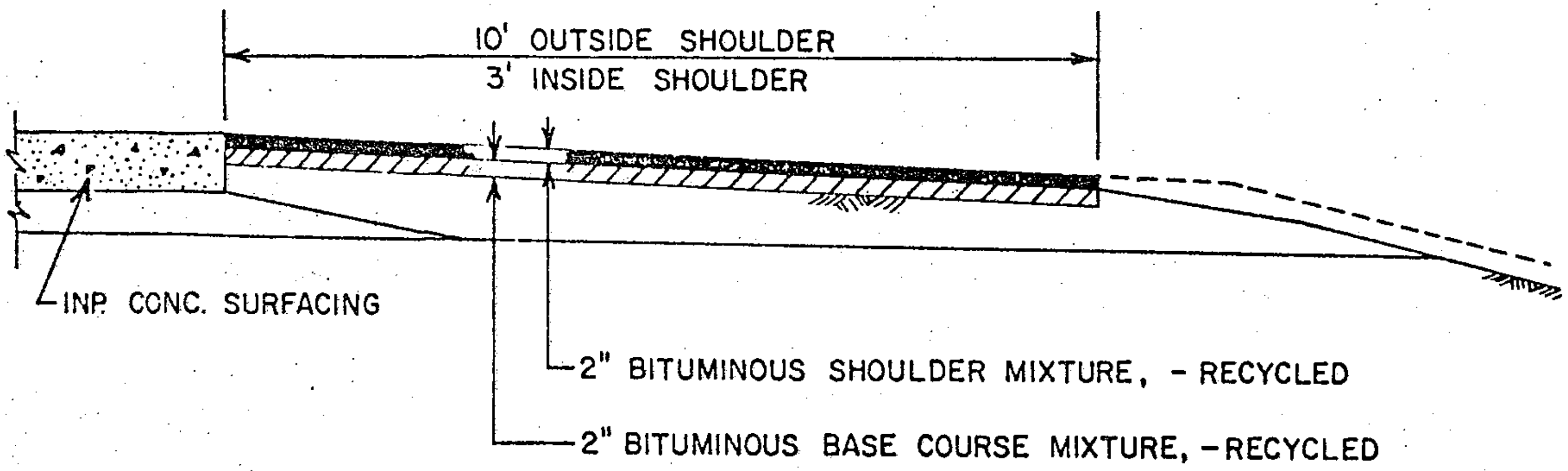
1. After asphalt extraction except samples from virgin agg. stockpile.
2. Virgin aggregate stockpile at plant.
3. Milling cut 1½" depth old wearing course only.
4. Milling cut 3½" depth includes old binder and wearing courses.
5. Conventional bituminous mix using virgin aggregate.

S.P. 5380-79 T.H. 090
Beaver Creek to Worthington
Letting Date: September 26, 1980
Contractor: KOMATZ CONSTRUCTION, INC.
Type of Work: Pavement Joint and Crack Repair and Recycled Bituminous Mixture

Trunk Highway 090 is a four-lane Interstate freeway that crosses southern Minnesota. The contract, among other things, called for removal of the existing 2" bituminous shoulder and 2" of the underlying gravel base. The contractor had the option to recycle these materials into 2" 2331 bituminous base and 2" 2331 shoulder wearing course. This project was in design prior to the development of our permissible recycling specification 2332. The resulting plans and special provisions are a hybrid of previous and current thinking.

SP 5380-79
TH 90

BITUMINOUS SHOULDER SURFACING DETAIL



SP 5380-79 TH 90

PARTIAL ABSTRACT OF BIDS

DATE OF AWARD 10-6-80

	Estimate	Komatz	Hodgman	McLaughlin	D. & G.	H. Schultz	Hardrives
SALVAGE BITUMINOUS:	0.44 48,859	0.33 36,644	0.69 76,620	0.80 88,835	0.85 94,387	0.84 93,276	1.54 171,007
SALVAGE AGGREGATE:	0.62 68,847	0.33 36,644	0.56 62,184	0.80 88,835	0.75 83,283	0.69 76,620	1.54 171,007
ASPHALT CEMENT:	107.00 165,101	110.00 169,730	101.50 156,614	165.00 254,595	125.00 192,875	165.00 254,595	108.00 166,644
BASE COURSE:	8.86 105,132	6.50 77,129	6.98 82,824	4.63 54,939	6.50 77,129	10.00 118,660	7.25 86,028
SHOULDER WEAR:	9.10 107,980	6.50 77,129	6.98 82,824	4.63 54,939	6.50 77,129	10.00 118,660	7.25 86,028
TOTAL:	495,920	397,277	461,068	542,144	524,803	661,812	680,716

S.P. 4309-20 T.H. 212
W. McLeod Co. Line to Jct. T.H. 22
Length: 14 Miles
Letting Date: November 21, 1980
Contractor: W. HODGEMAN & SONS, INC.
Type of Work: Bituminous Overlay and Shoulders

This section was surfaced with 9-7-9 non-reinforced portland cement concrete, 20 feet wide with 40'-4" joint spacing in 1929. From 4 to 6 inches of gravel base and four inches of plant-mixed bituminous was placed in 1961. A 5/8" plant mixed bituminous surface 24' wide was placed in 1973. An evaluation in May, 1979 showed a Serviceability Rating of 2.8, a Structural Rating of 1.9 and a Condition Rating of 2.3. The proposed rehabilitation design was to remove 1½" of the existing surface 26 feet in width. Place 1½" 2331 P.M. levelling course and 1½" 2341 P.M. wearing course with variable depth P.M. bitumen 2331 shoulder.

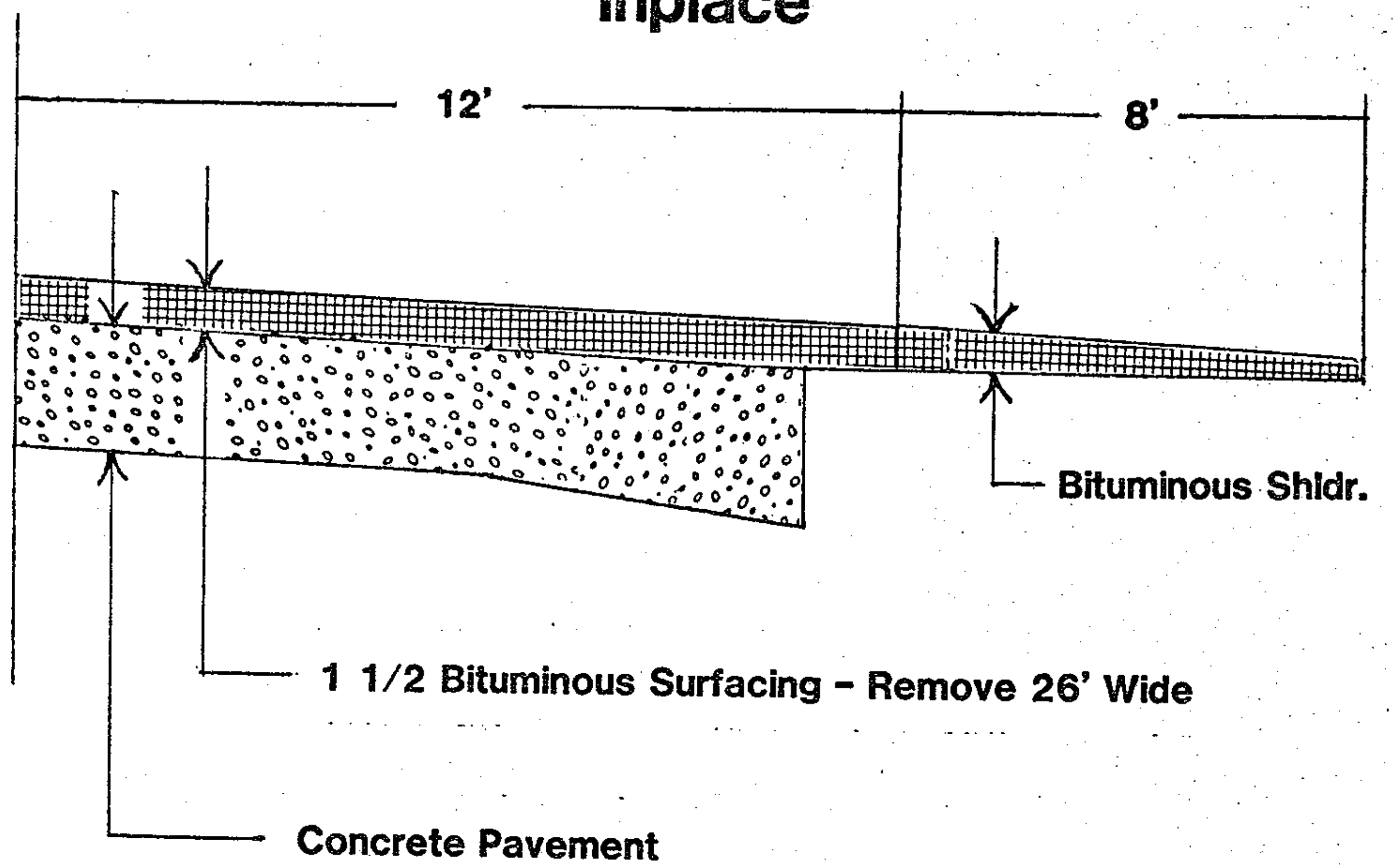
The contractor for this project also was the successful bidder on an adjacent project S.P. 6511-13, T.H. 212. This adjacent project had excess salvageable bituminous mixture therefore the contractor requested a supplemental agreement under specification 1408 Value Engineering Incentive to produce the 2341 wearing course mixture with 50% salvaged and 50% virgin materials.

This was the first project to be constructed with a 2341 recycled wearing course.

SP 4309-20

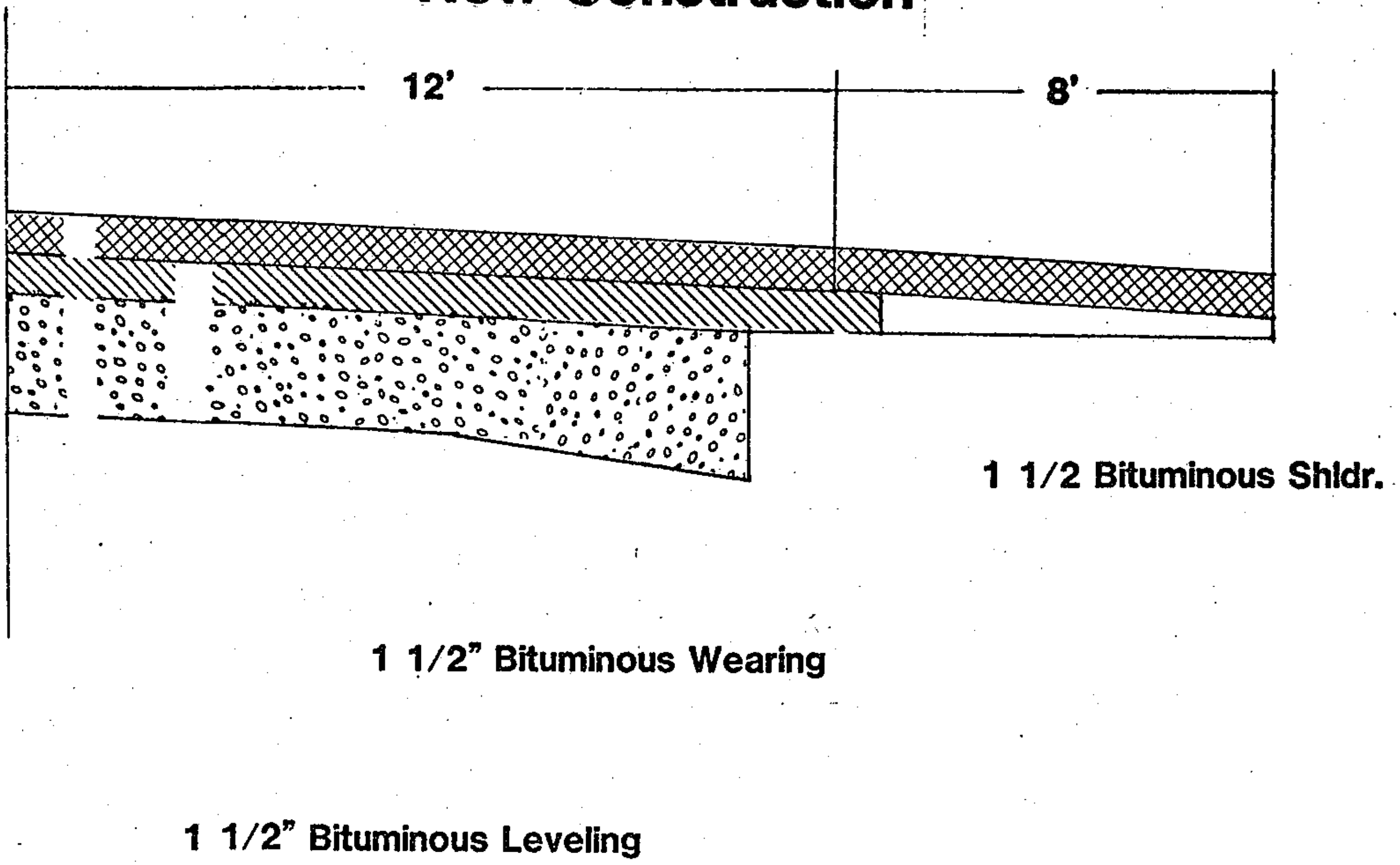
TH 212

Inplace



SP 4309-20

TH 212
New Construction



SP 4309-20 TH 212

PARTIAL ABSTRACT OF BIDS

DATE OF AWARD 12-3-80

	Estimate	Hodgman	Komatz	Hardrives	D. & G.	McLaughlin	Mooneys	Fairway
BITUMINOUS REMOVAL:	0.84 173,413	0.47 97,029	0.60 123,867	0.52 107,351	0.78 161,027	0.60 123,867	0.71 146,575	0.72 148,640
ASPHALT CEMENT:	113.30 269,087	98.00 232,750	100.00 237,500	103.00 244,625	87.50 207,812	115.00 273,125	152.00 361,000	153.00 363,375
LEVELING COURSE:	8.11 164,754	6.77 137,532	6.50 132,047	5.90 119,858	7.90 160,488	8.58 174,302	10.09 204,978	10.40 211,276
SHOULDER MIXTURE:	9.35 142,596	7.53 114,840	6.50 99,131	5.90 89,980	8.40 128,108	9.36 142,749	10.44 159,220	10.40 158,610
A.C. FOR WEAR 2341:	163.00 193,481	130.00 154,310	160.00 189,920	153.00 181,611	150.00 178,050	150.00 178,050	152.00 180,424	153.00 181,611
WEARING COURSE:	10.00 158,320	9.03 142,962	7.00 110,824	11.60 183,651	9.77 154,678	10.58 167,502	12.20 193,150	10.40 164,652
TOTAL:	1,101,653	879,424	893,290	927,078	990,165	1,059,596	1,245,349	1,228,165

S.P. 6511-23 T.H. 212
Renville County, from 10th Street in Olivia to the East County Line
Length: 24.9 Miles
Letting Date: April 24, 1981
Contractor: W. HODGEMAN & SONS, INC.
Type of Work: Bituminous Resurfacing

The subgrade was graded in 1930 to a width of 40 feet. A 9-7-9 portland cement concrete pavement 20 feet wide with 40'4" joint spacing was placed in 1931.

In 1958 the existing concrete pavement was surfaced with 1½" levelling course, a 1½" binder course and a 1½" wearing course.

In 1971 a 3/4" plant mixed bituminous wearing course 24' wide was placed.

An evaluation in 1980 (Olivia to Bird Island) showed a Serviceability Rating of 3.2, a Structural Rating of 1.6 and a Condition Rating of 2.4; from Bird Island to the E. County Line a Serviceability Rating of 3.2, a Structural Rating of 0.8 and a Condition Rating of 2.0.

The rehabilitation design called for removing the existing bituminous mixture on the mainline and shoulders on the rural section of the project. Test areas indicated an average depth of 5½" of bituminous mixture over the existing portland cement concrete pavement on the rural sections, except on the research section No. 265 from Sta. 950-1029 where cores averaged 7½ inches in depth. After removal, the first 1/2 of leveling course mixture would be placed by tight blading over the exposed concrete pavement with the intent of filling depressions. The proposed typical section consists of 7" 2331 Plant Bituminous Base, 2" 2331 bituminous levelling, 1½" 2331 binder and 3/4" 2361 wearing course. Urban areas had special typical sections which will not be overed in this report.

The special provisions allowed recycled bituminous mixture conforming to Specification 2332 in lieu of conventional mixtures at the option of the contractor.

Extraction tests show the asphalt cement content of the surface is approximately as follows:

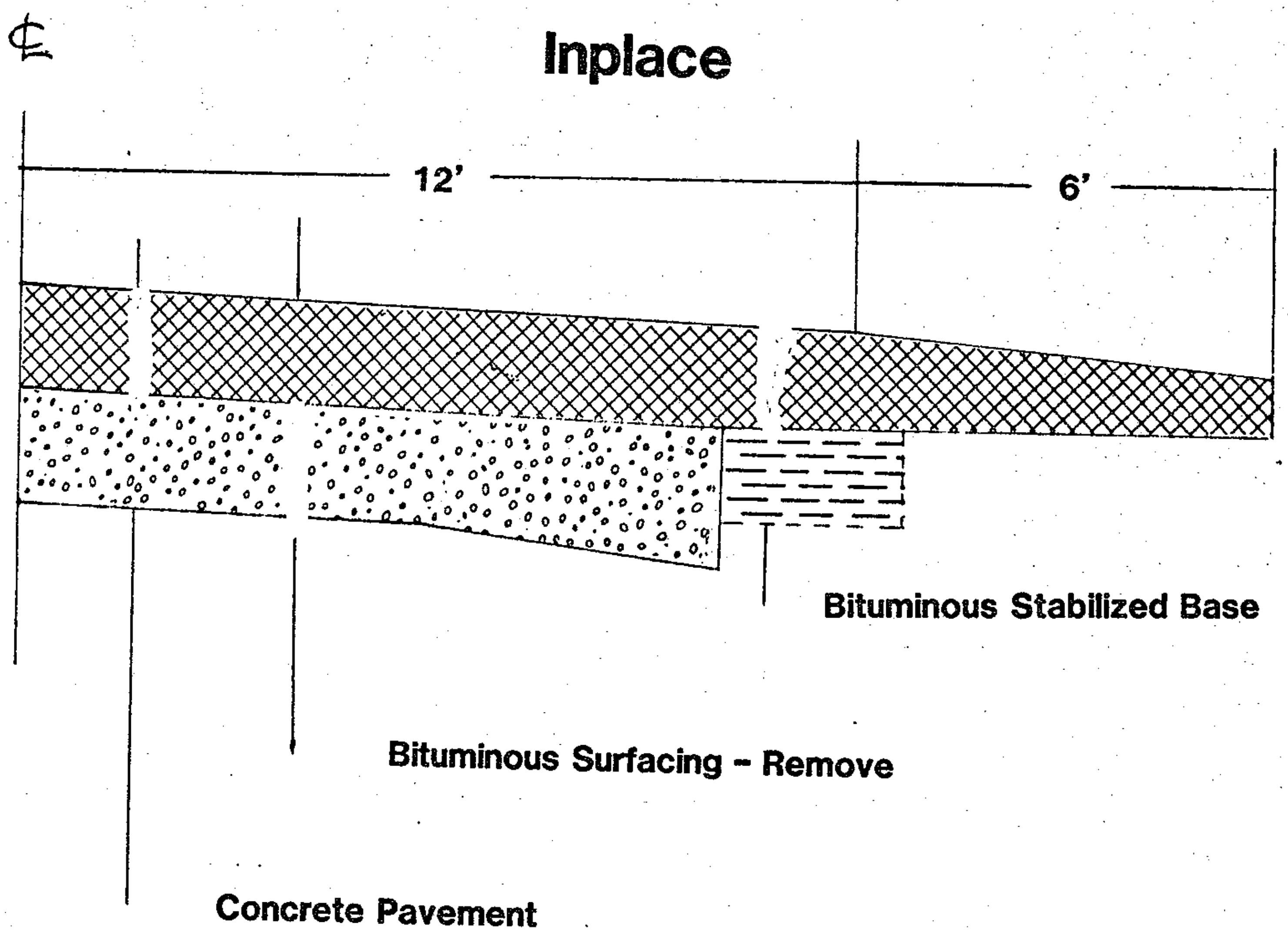
Depth	Asphalt Cement
0-3/4"	7.4%
3/4 - 2¼"	5.1%
2¼ - 3-3/4"	3.7%

Below 3-3/4 a lean mixture exists, however, no tests were taken.

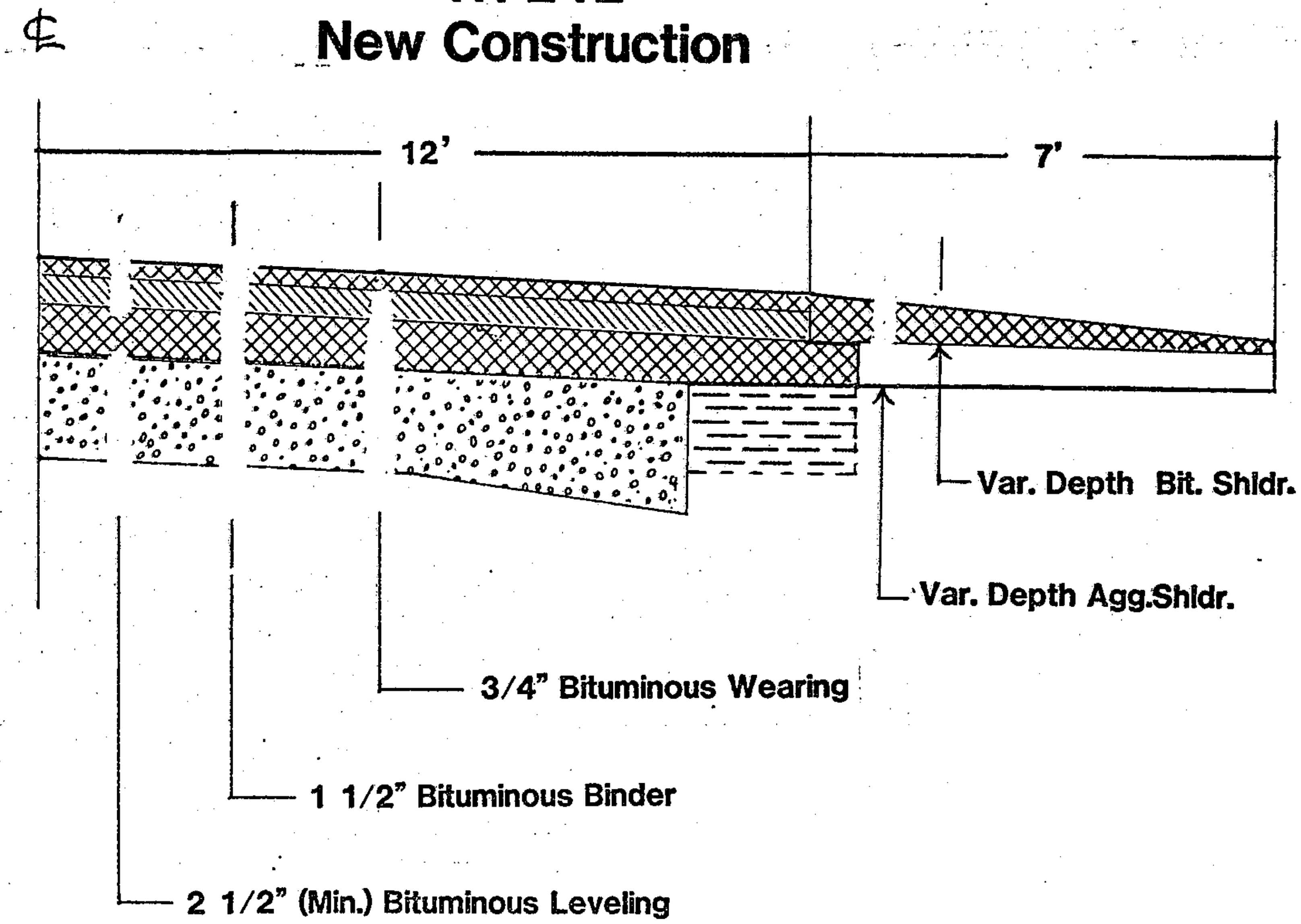
Bidders were allowed to take bituminous samples to run their own extraction tests. Contractor to provide traffic control and patching of the surface.

The Contractor has been producing a recycled mixture at a 70-30 blend of salvaged bituminous material to clean aggregate. It appears he will have surplus material for use on another contract in the area.

SP 6511-23
TH 212
Inplace



SP 6511-23
TH 212
New Construction



PARTIAL ABSTRACT OF BIDS

SP 6511-23

DATE OF AWARD 5-13-81

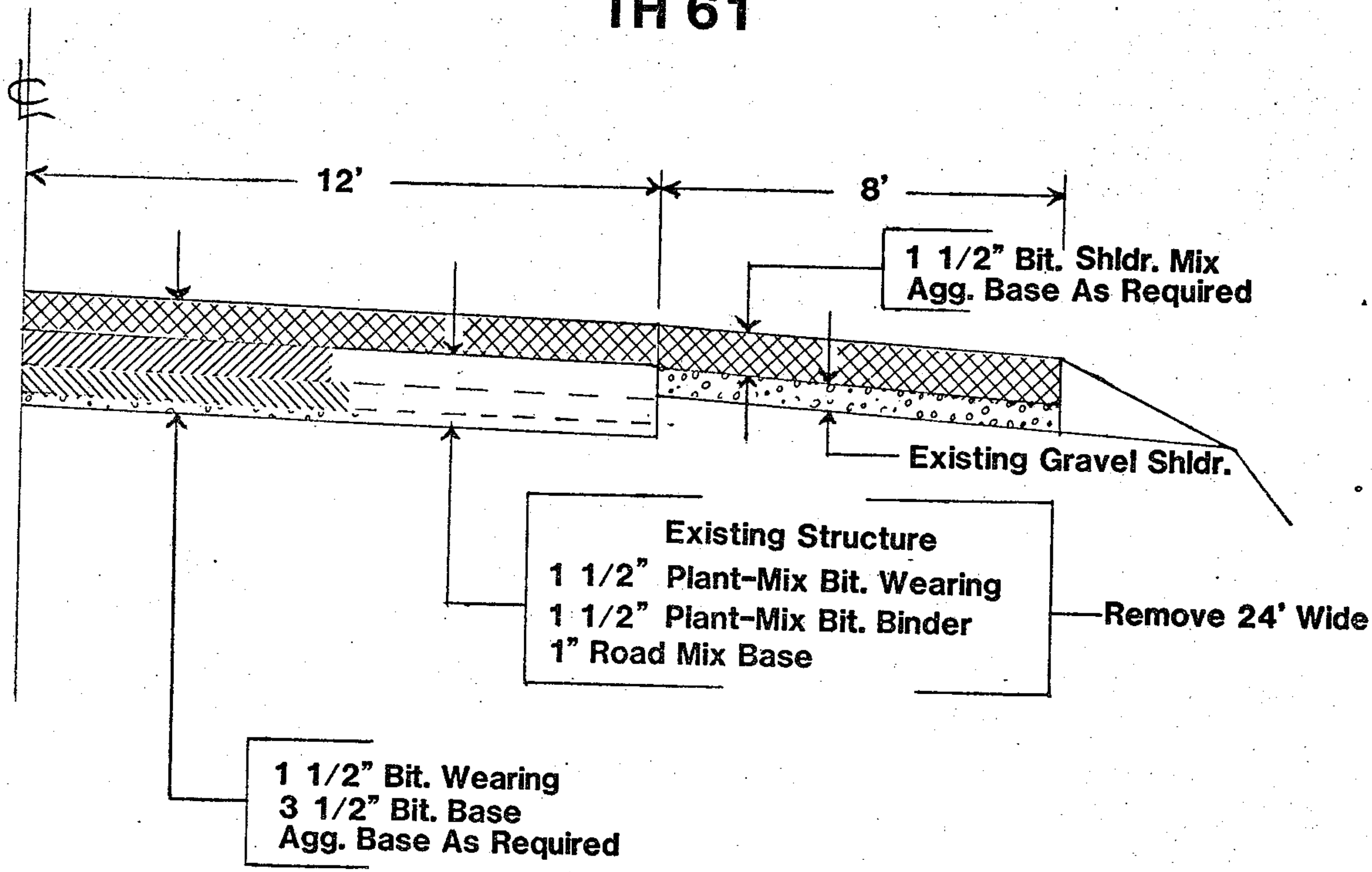
	Estimate	Hodgman	Komatz	D. & G.	N.D.H.
BITUMINOUS REMOVAL:	0.68 332,044	0.47 229,501	0.80 390,640	0.50 244,150	1.30 634,791
ASPHALT CEMENT:	95.00 522,595	75.00 412,575	68.00 374,068	101.04 555,821	150.00 825,150
BINDER COURSE:	7.38 202,691	7.98 219,170	7.60 208,734	7.55 207,360	7.00 192,255
LEVELING COURSE:	7.38 403,818	7.93 433,913	7.60 415,856	7.55 413,120	7.00 383,026
BASE COURSE:	11.09 20,039	8.00 14,456	7.60 13,733	7.55 13,642	7.00 12,649
SHOULDER MIXTURE:	8.92 237,200	8.63 229,488	7.60 202,099	8.05 214,065	7.00 186,144
A.C. FOR WEAR:	215.00 234,350	220.00 239,800	225.00 245,250	219.65 239,418	230.00 250,700
WEARING COURSE:	19.88 309,611	16.80 259,774	17.50 272,545	15.53 241,864	16.50 256,971
TOTAL:	2,262,351	2,038,679	2,122,927	2,129,444	2,741,686

S.P. 1604-26 T.H. 61
Grand Portage to Pigeon River
Length: 7.46 Miles
Letting Date: December 19, 1980
Contractor: ULLAND BROS., INC.
Type of Work: Bituminous Surfacing and Shoulders

This roadbed was paved in 1962 with 1½" 2331 wearing, 1" 2331 binder and 1" road mix bituminous base over 3" to 8" of aggregate base. The shoulders were gravel surfaced. This is a aggregate scarce area.

The proposal called for removing the existing bituminous materials. Recycled bituminous mixture conforming to specification 2332 may be substituted for conventional mixtures (base, binder, levelling, wearing and shoulder mixture) at the option of the contractor. This was the first project in Mn/DOT to allow a recycled wearing course mixture. This project and the T.H. 212 are being used for a Minnesota Local Road Research Board study to evaluate recycled wearing course mixtures. Extraction tests run on three random cores show an average asphalt content of 3.2%.

SP 1604-26
TH 61



PARTIAL ABSTRACT OF BIDS

SP 1604-26 TH 61

DATE OF AWARD 2-6-81

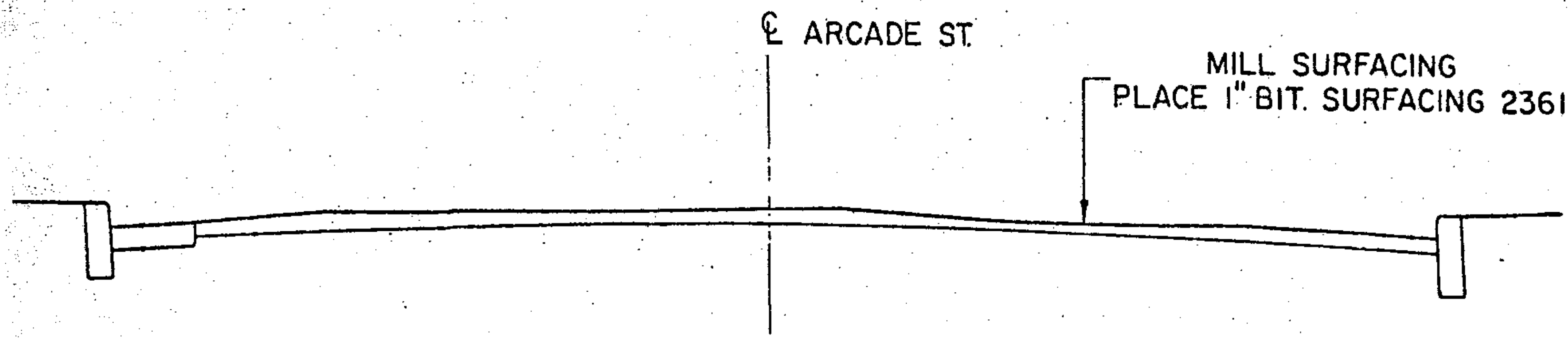
	Estimate	Ulland	Komatz	Premier	D. & G.	E. W. Coons
BITUMINOUS REMOVAL:	0.73 66,621	1.16 105,865	1.00 91,263	0.40 36,505	1.04 94,913	1.00 91,263
ASPHALT CEMENT:	164.00 297,332	137.00 248,381	160.00 290,080	210.00 380,730	195.00 353,535	210.00 380,730
WEAR COURSE:	8.22 86,499	6.25 65,768	8.35 87,867	8.65 91,023	8.17 85,972	10.70 112,596
BASE COURSE:	8.38 155,331	6.25 115,850	8.35 154,775	8.65 160,336	8.17 151,439	10.70 198,335
SHOULDER WEAR:	9.00 52,074	6.25 36,162	8.35 48,313	9.15 52,941	8.17 47.271	11.10 64.224
TOTAL:	657,895	572,027	672,298	721,537	847,148	847,148

S.P. 6221-30 T.H. 61
East 7th Street to Larpenteur Avenue in St. Paul
Length: 2.06 Miles
Letting Date: April 24, 1981
Contractor: ASHBACH CONSTRUCTION CO.
Type of Work: Milling and Bituminous Resurfacing

The plans called for removal of approximately a 1" wearing course and replacement with 1" 2361 wearing course. This proposal did not contain the recycling option. This was the only contractor that gave us a credit for the salvaged wear course. It is estimated that the state received a value of $5 per ton of material removed. Other bidders did not appear to provide a credit, therefore, they did not get the job. The contractor planned to recycle this material on another state contract in St. Paul.

SP 6221-30

TH 61



SP 6221-30 ARCADE STREET TH 61 **PARTIAL ABSTRACT OF BIDS**

DATE OF AWARD 5-21-81

	Milling Surface	Asphalt Cement	Wearing Course	Total
ESTIMATE	1.10	176.82	20.14	
	43,100	39,784	60,480	143,365
ASCHBACH	0.60	200.00	20.00	
	23,509	45,000	60,060	128,569
HARDRIVES	1.19	200.00	17.80	
	46,626	45,000	53,453	145,079
TOTAL	1.15	215.00	17.75	
	45,059	48,375	53,303	146,737
TOWER	1.10	215.00	19.00	
	43,100	48,375	57,057	148,532
PROGRESSIVE	1.20	200.00	18.00	
	47,018	45,000	54,054	146,072
McCROSSAN	2.07	210.00	18.00	
	81,106	47,250	54,054	182,410

S.P. 5601-21 T.H. 210
Fergus Falls to Breckenridge
Length: 17.93 Miles
Letting Date: February 27, 1981
Contractor: DUININCK BROTHERS & GILCHRIST
Type of Work: Widening, Bituminous Resurfacing and Shouldering

This section was surfaced with 9-7-9 non-reinforced portland cement concrete pavement, 20' wide, with 40'4" joint spacing in 1931. In 1952, the pavement was widened 1½' with 6" bituminous base and overlayed with 3½" of plant mixed bituminous 22' in width. In 1968, the roadway was overlayed with 1½" of bituminous P.M. wearing course. The shoulders were 3-4" thick aggregate 6-8 feet in width. The bituminous portion of the roadway was severely cracked about every four feet (transverse and block cracking). The 1978 condition rating was 2.3. The ESAL for a 20 year design is 639,500. This is a 10-ton route.

The rehabilitation plans, among other things, called for the removal of the bituminous surfacing, widening and shouldering. The existing concrete pavement was to be cracked every 5 feet, rolled with a heavy roller to seat the slabs and cleaned. After cleaning a 1" 2331 levelling course was placed (tight bladed with a motor graded into all joints, cracks and spalled areas). Prior to cracking the pavement a new widened base section approximately 9" of 2331 bituminous base was placed on either side. One inch and 2 inches of 2331 levelling course, 1½" 2331 binder, and 1½" 2341 wearing course was placed over the widened pavement. After variable depth aggregate shouldering was placed, 2½" 2331 base and 1½" 2331 wearing course were placed on the shoulders. Recycled bituminous mixture conforming to the requirements of recycling specification 2332 may be substituted for conventional mixtures (base, binder, levelling and shoulder wearing) at the option of the contractor.

The contractor elected to use the recycling option. The test results are as shown below.

SP 5601-21

TH 210

TRIAL MIX RESULTS

Ratio Salv./Virgin	Mix Type	Asphalt Cement		Density (pcf)	Flow (inches)	Stability (lbs.)	Air Voids (% in Mix)	CWA (% Loss)
		% Added	Pen Grade					
~~40/60~~ 60/40	B.Bi.&Lv.(1)	1.4	120/150	138.4	.06	2785	11.7	18.9
~~40/60~~	"	3.3	120/150	142.0	.07	2028	5.8	--
~~40/60~~	"	2.0	120/150	138.0	--	2262	8.8	11.5

Asphalt Recommendation: add 2.3% new A.C.

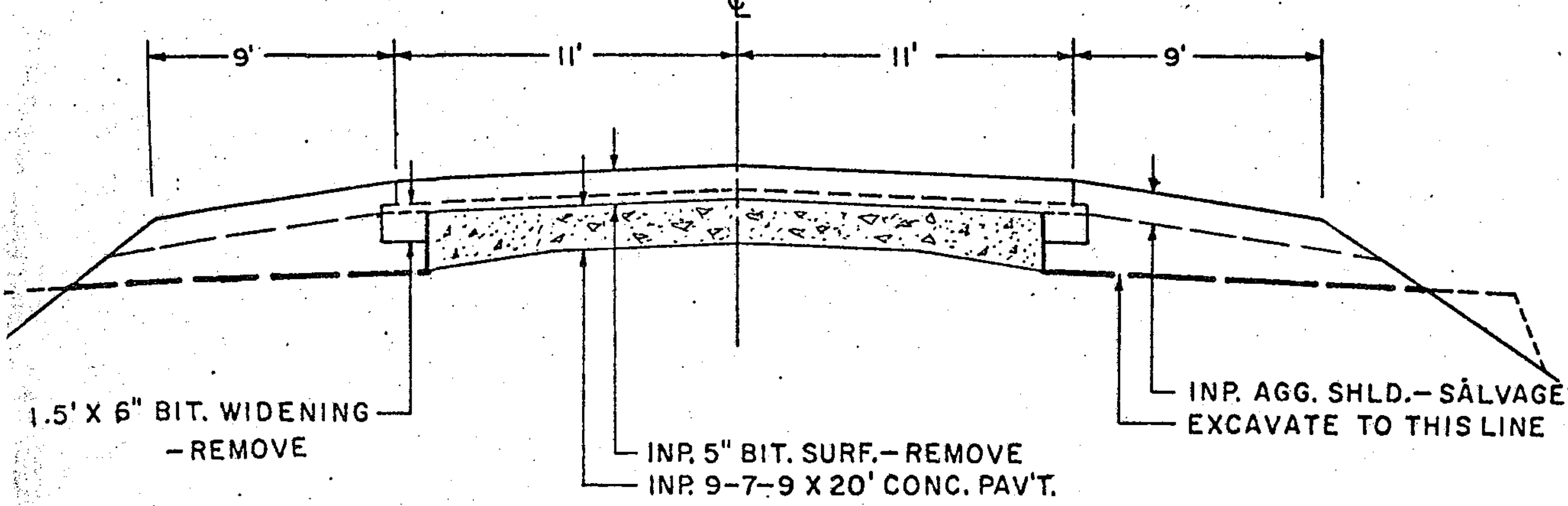
1. Base, Binder & Levelling.

EXTRACTION RESULTS

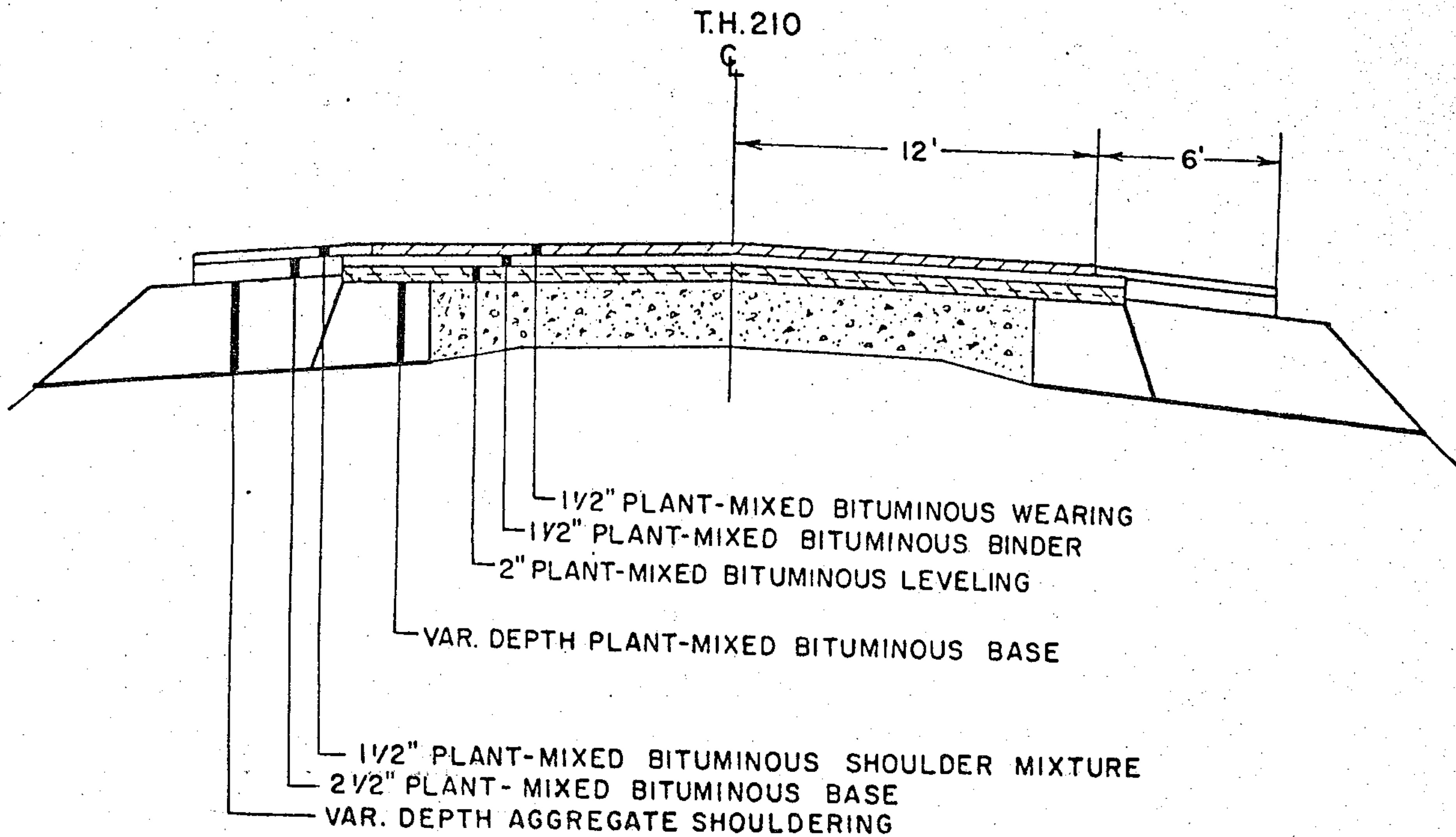
Course	Samples	% A.C.
Base, Binder & Levelling	Field (n=34)	4.81

SP 5601-21

INPLACE
T.H.210



SP 5601-21



T.H. 210
CL
12'
6'
1 1/2" PLANT-MIXED BITUMINOUS WEARING
1 1/2" PLANT-MIXED BITUMINOUS BINDER
2" PLANT-MIXED BITUMINOUS LEVELING
VAR. DEPTH PLANT-MIXED BITUMINOUS BASE
1 1/2" PLANT-MIXED BITUMINOUS SHOULDER MIXTURE
2 1/2" PLANT-MIXED BITUMINOUS BASE
VAR. DEPTH AGGREGATE SHOULDERING

PARTIAL ABSTRACT OF BIDS

SP 5601-21 TH 210

DATE OF AWARD 4-9-81

	Estimate	D & G	Komatz	S & S	F-M	Mooneys	Mark	B-S	No. Imp.	Thorson
BITUMINOUS REMOVAL:	1.42 313,864	0.92 203,348	1.35 298,391	0.80 176,824	0.69 152,511	1.20 265,237	0.68 150,301	0.45 99,463	1.20 265,237	1.30 287,340
PAVEMENT BREAKING:	97.50 88,042	80.00 72,240	66.00 59,598	47.00 42,441	35.00 31,605	85.00 76,755	100.00 90,300	100.00 90,300	165.00 148,995	150.00 135,450
ASPHALT CEMENT:	95.00 430,635	110.00 498,630	130.00 589,290	106.00 480,498	110.00 498,630	105.18 476,780	211.00 956,463	166.00 752,478	135.00 611,955	215.00 974,595
2331 WEAR:	9.05 54,300	7.00 42,000	8.10 48,600	8.00 48,000	7.00 42,000	9.78 58,680	8.93 53,580	7.95 46,200	13.00 78,000	12.00 72,000
BINDER COURSE:	7.20 122,587	6.75 114,925	7.15 121,735	7.50 127,695	5.75 97,899	7.03 119,692	7.25 123,438	7.95 135,356	10.00 170,260	7.50 127,695
LEVELING COURSE:	7.20 138,060	6.75 129,431	5.50 105,462	7.50 143,812	6.00 115,050	7.09 135,950	7.25 139,018	7.95 152,441	11.10 212,842	7.50 143,812
BASE COURSE:	7.20 304,444	6.75 285,417	5.50 232,562	7.50 317,130	7.50 317,130	7.16 302,753	7.25 306,559	7.50 317,130	10.00 422,840	7.50 317,130
SHOULDER MIXTURE:	8.95 95,648	7.05 75,343	5.50 58,778	7.50 80,152	5.50 62,122	7.50 81,541	6.00 77,480	7.63 84,961	10.00 106,870	8.00 85,496
A.C. FOR WEAR:	178.00 224,814	198.80 251,084	226.00 285,438	210.00 265,230	210.00 265,230	209.00 263,967	211.00 266,493	192.00 242,496	200.00 252,600	215.00 271,545
2341 WEAR:	7.90 158,395	6.08 121,904	7.30 146,365	7.50 150,375	8.35 167,417	8.12 162,806	8.15 163,407	8.30 166,415	12.50 250,625	8.00 160,400
TOTAL:	1,930,791	1,794,324	1,946,222	1,832,159	1,749,595	1,944,165	2,327,042	2,087,243	2,520,225	2,575,464

ECONOMIC ANALYSIS

It is difficult to present the amount of savings attributed to recycling. We will attempt to give you a feel for what these savings might be with three illustrative comparisons, expressed as percentages. We will also illustrate the estimated reduction in new asphalt cement required.

1. Difference between the engineer's estimate and the successful bid price for recycled bituminous items.

2. Difference between the engineer's estimate and the cost of all bituminous items assuming all new asphalt cement for an exclusively conventional mix pavement.

3. Difference between the successful bid price and the cost of all bituminous items assuming all new asphalt cement for an exclusively conventional mix pavement.

4. Reduction in new asphalt cement, total tons.

SUMMARY OF ECONOMIC ANALYSIS

	Recycled Mixture Tons	AC Saved Tons	Total A.C. Savings	Total Savings	Est. Cost of Recycled Mix	Cost of Recycled Mix/To
T.H. 90	23,732	514	84,865.00	183,508.86	323,989	13.65
T.H. 212	51,398	585	76,000.00	243,701.07	782,395	15.22*
T.H. 212	110,582	3625	797,645.00	976,929.60	1,309,602	11.84
T.H. 61	34,861	630	132,349.00	218,217.34	466,162	13.37*
T.H. 210	95,245	2660	402,530.40	528,776.80	1,145,747	12.03
	315,818	8014	$1,493,389.40	$2,151,133.60	$4,027,895	$12.75

* These projects include recycled wearing course mixtures

$4.73/Ton Avg. Savings based on assumed asphalt cement savings

$$\frac{\$1,493,389.40}{315,818 \text{ Ton}}$$

Range $1.47-$7.21

$6.81/Ton Avg. savings based on difference between engineer est. and successful bidder plus asphalt cement savings

$$\frac{\$2,151,133.60}{315,818 \text{ Ton}}$$

Range $4.74 - $8.83

These five projects were selected at random to illustrate the economic savings attributable to recycling. The average savings per ton based on the estimated tons of recycled mix of 315,818 versus the assumed savings in new asphalt cement($1,493,389.40) and the total estimated savings ($2,151,133.60) based on the engineers estimate are $4.73/Ton and $6.81/Ton. The range is from $1.47 - $7.21/Ton and $4.74 - $8.83/Ton respectively for the five projects. If the same trend follows for other recycling projects we could assume a savings of $473,000 - $681,000 per 100,000 tons on other projects under construction this season.

If we assume that 10% of the estimated total of 12 million tons of hot mix is produced annually on all projects in Minnesota, the estimated annual savings attributable to recycled hot mix could range from $5,676,000 to $8,172,000. We can assume that $5,676,000 is reduced cost of new asphalt cement.

S.P. 5601-21 (T.H. 210)
DUININCK BROS. AND GILCHRIST
Contract Letting Date: February 27, 1981

This project allowed recycled mixtures for base, binder, levelling and shoulder wearing course mixtures. The cost of new asphalt cement for Conventional mixture used was the price bid for 2391 wearing course mixture.

1. Engineer's Estimate — $1,547,582.00
   Less Successful Bid — - 1,421,335.60
   Difference — $126,246.40

   (Difference ÷ Engineer's Estimate) x 100

   $$\frac{126,246.40}{1,547,582.00} \times 100 = 8.16\%$$

2. Assumed AC Price/Ton, Conventional Mix — 198.80
   Less AC Bid Price/Ton, Recycled Mix — - 110.00
   Difference, Conventional vs. Recycled — 88.80

   AC Required for Project — 4533 tons

   Difference (Conv. vs. Recycled) x AC Required

   88.80 x 4533 = $402,530.40

   Plus Difference from (1) — + 126,246.40

   Total Difference, Conventional vs. Recycled — $528,776.80

   (Total Difference ÷ Engineer's Estimate) x 100

   $$\frac{528,776.80}{1,547,582.00} \times 100 = 34.17\%$$

3. (Total Difference ÷ Successful Bid) 100

   $$\frac{528,776.80}{1,421,335.60} \times 100 = 37.20\%$$

4. Difference for AC (Conv. vs. Recycled) = Estimated reduction of new AC required

   $$\frac{\$402,530.40}{\$198.80 \text{ Ton}} = 2,660 \text{ Tons}$$

S.P. 5380-79 (T.H. 090)
KOMATZ CONSTRUCTION, INC.
Contract Letting Date: October 6, 1980

This project allowed recycled mixtures for base and shoulder wearing courses. Therefore, the cost of new asphalt cement for a conventional mixture for item 2 was taken from two other bidders, McLaughlin & Schultz and Hugo Schultz. Assuming these bid prices reflect the use of conventional mix.

1. Engineer's Estimate — $495,920.90
   Less Successful Bid — -397,277.04

   Difference — $98,643.86

   (Difference ÷ Engineer's Estimate) x 100

   $$\frac{\$98,643.86}{\$495,920.90} \times 100 = 19.89\%$$

2. Assumed AC Price/Ton, Conventional Mix — $ 165.00
   Less AC Bid/Ton, Recycled Mix — - 110.00

   Difference, Conventional vs. Recycled — 55.00

   AC Required for Project — 1543 Tons
   Difference (Conv. vs. Recycled) x AC Required
   55.00 x 1543 = $84,865.00

   Plus Difference from (1) — + 98,643.86

   Total Difference, Conventional vs. Recycled — $183,508.86

   (Total Difference ÷ Engineer's Estimate) x 100

   $$\frac{\$183,508.86}{\$495,920.90} \times 100 = 37.00\%$$

3. (Total Difference ÷ Successful Bid) 100

   $$\frac{\$183,508.86}{\$397,277.04} \times 100 = 46.19\%$$

4. $$\frac{\text{Difference for AC (Conv. vs. Recycled)}}{\text{Assumed AC Price/Ton}} = \text{Estimated reduction of new AC required}$$

   $$\frac{\$84,865.00}{\$165.00/\text{Ton}} = 514 \text{ Tons}$$

S.P. 4309-20 (T.H. 212)
W. HODGEMAN & SONS, INC.
Contract Letting Date: December 3, 1980

This project allowed recycled mixtures for base, binder, levelling and shoulder wearing course mixtures. The cost of new asphalt cement for conventional mixture used was the price bid for 2341 wearing course mixture.

1. Engineer's Estimate — $749,852.80
   Less Successful Bid — -582,151.73

   Difference — $167,701.07

   (Difference ÷ Engineer's Estimate) x 100

   $$\frac{\$167,701.07}{\$749,852.80} \times 100 = 22.36\ \%$$

2. Assumed AC Price/Ton, Conventional Mix — $ 130.00
   Less AC Bid/Ton, Recycled Mix — - 98.00

   Difference, Conventional vs. Recycled — $ 32.00

   AC Required for Project — 2375 Tons
   Difference (Conv. vs. Recycled) x AC Required

   $32.00 x 2375 = $76,000.00

   Plus Difference from (1) — +$167,701.07

   Total Difference, Conventional vs. Recycled — $243,701.07

   (Total Difference ÷ Engineer's Estimate) x 100

   $$\frac{\$243,701.07}{\$749,852.80} \times 100 = 32.50\%$$

3. (Total Difference ÷ Successful Bid) 100

   $$\frac{\$243,701.07}{\$582,151.73} \times 100 = 41.86\%$$

4. Difference for AC (Conv. vs. Recycled) ÷ = Estimated reduction of new AC required

   Assumed AC Price/Ton

   $$\frac{\$76,000.00}{\$130.00\text{Ton}} = 585 \text{ Tons}$$

S.P. 6511-23 (T.H. 212)
W. HODGEMAN & SONS, INC.
Contract Letting Date: May 13, 1981

This project allowed recycled mixtures for base, binder, levelling and shoulder wearing course mixtures. The cost of new asphalt cement for conventional mixture used was the price bid for 2361 wearing course mixture.

1. Engineer's Estimate — $1,718,390.50
   Less Successful Bid — − 1,539,105.90

   Difference — $179,284.60

   (Difference ÷ Engineer's Estimate) x 100

   $$\frac{\$179,284.60}{\$1,718,390.50} \times 100 = 10.43\%$$

2. Assumed AC Price/Ton, Conventional Mix — $ 220.00
   Less AC Bid/Ton, Recycled Mix — − 75.00

   Difference, Conventional vs. Recycled — $ 145.00

   AC Required for Project — 5501 Tons
   Difference (Conv. vs. Recycled) x AC Required

   $145 x 5501 = $ 797,645.00

   Plus Difference from (1) — + 179,284.60

   Total Difference, Conventional vs. Recycled — $ 976,929.60

   (Total Difference ÷ Engineer's Estimate) x 100

   $$\frac{\$976,929.60}{\$1,718,390.50} \times 100 = 56.85\%$$

3. (Total Difference ÷ Successful Bid) 100

   $$\frac{\$976,929.60}{\$1,539,105.90} \times 100 = 63.47\%$$

4. Difference for AC (Conv. vs. Recycled) ÷ = Estimated reduction of new AC required

   Assumed AC Price/Ton

   $$\frac{\$797,645.00}{\$220/\text{Ton}} = 3625 \text{ Tons}$$

S.P. 1604-26 (T.H. 61)
ULLAND BROS., INC.
Contract Letting Date: February 6, 1981

This project allowed recycled mixtures for base, binder, levelling and in addition the wearing course mixture. Therefore, the cost of new asphalt cement for conventional mixture for item 2 and 3 was taken from two other bidders, Premier and E. W. Coons.

1. Engineer's Estimate — $657,895.67
   Less Successful Bid — - 572,027.33

   Difference — $ 85,868.34

   (Difference ÷ Engineer's Estimate) x 100

   $$\frac{\$85,868.34}{\$657,895.67} \times 100 = 13.05\%$$

2. Assumed AC Price/Ton, Conventional Mix — $ 210.00
   Less AC Bid/Ton, Recycled Mix — - 137.00

   Difference, Conventional vs. Recycled — $ 73.00

   AC Required for Project — 1813 Tons
   Difference (Conv. vs. Recycled) x AC Required

   $73.00 x 1813 = $132,349.00

   Plus Difference from (1) — + 85,868.34

   Total Difference, Conventional vs. Recycled — $218,217.34

   (Total Difference ÷ Engineer's Estimate) x 100

   $$\frac{\$218,217.34}{\$657,895.67} \times 100 = 33.16\%$$

3. (Total Difference ÷ Successful Bid)100

   $$\frac{\$218,217.34}{\$572,027.33} \times 100 = 38.15\%$$

4. Difference for AC (Conv. vs. Recycled) ÷ Assumed AC Price/Ton = Estimated reduction of new AC required

   $$\frac{\$132,349.00}{\$210/\text{Ton}} = 630 \text{ Tons}$$

CONCLUSIONS

Keys to implementation of recycling in Minnesota:

1. Coordination and cooperation between Mn/DOT and the contracting industry.

2. Support from top staff and key individuals.

3. Minnesota Local Road Research Board.

4. Permissible specifications which allow recycled mixtures in lieu of conventional mixtures on all projects.

5. Establishing value for salvageable material.

6. Move toward end-result specifications.

7. Payment for old asphalt cement in recycled mixtures.

8. Recognition that any project may include resurfacing, reconditioning and reconstruction design alternatives in the rehabilitation plans, specifications and special provisions.

9. Performance at the least cost per unit of pavement as the goal of pavement evaluation, design and construction (13).

Each of us in this industry, whether a part of government or the private sector, has a role to play in maximizing the benefits of recycling. Each level of government and each sector of private enterprise must fulfill their role in the development of recycling policy and procedure to optimize the benefits.

The federal government should continue their efforts to stimulate and advance the implementation of recycling.

The states should provide the specification and quality control for recycled mixes. Most important, they should allow the use of recycled mixes as an equal to standard conventional mixes provided they meet mix design and specification criteria. Policy on recycling should provide flexibility to allow the free market mechanism the ability to make the judgment of the most efficient resource allocation. The market mechanism must be allowed to work if we are to make the most efficient use of scarce, finite and costly materials.

The contractor, provided with a ready market for recycled mixes, should make the capital expenditures to modify their equipment and facilities to cost effectively recycle old pavement materials into new pavements. The contractors must determine the value of these materials less their acquisition costs (removal, haul, process) in relation to their potential value in a recycled pavement. The contractors should utilize the expertise of the equipment manufacturers in manufacturing new equipment and modifications to reduce cost of producing recycled mixes.

The governmental and private sector must work together to assure that recycling becomes standard operating procedure. There are no half way commitments that will get the job done. This requires a major commitment from the governmental agencies, federal, state, city and county to allow recycled mixes in lieu of the present conventional mixes. Without this commitment, the market for recycled mixes will be small and fragmented. We cannot expect the contracting industry to make the necessary commitments without having a substantial, definitive market. If we do not make this commitment,we all lose. We, as users, lose the ability to provide the taxpayers with more pavement for less dollars; the contractors lose the ability to make a profit; and the equipment manufacturers lose the sales of more productive equipment. In the end, our country and our way of life loses.

ACKNOWLEDGEMENTS

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APPENDIX A

PROJECT CHECK LIST

Rehabilitation Design:

What should be included in the plans, specifications and special provisions.

Materials available for recycling?

Characteristics of these materials?

Quantity of these materials?

Rehabilitation Alternatives:
a. alternate designs
b. alternate specifications

This information will let the contractors determine what alternate or combination of alternates will produce the desired end product as the least cost to the user.

Project Checklist
Pre-Letting
As-built records

Gradations
Asphalt Content
Quantities

Field Samples for Laboratory Testing

Asphalt Content of Each Course
Gradation of Salvageable Aggregate

Contractor Sampling

Allow contractor access to as-built records

Allow contractor to sample existing roadbed

Plans and Proposal

Include specific information on existing roadbed

Specifications and special provisions covering the work to be done and how it is paid for.

Construction

Contractor to submit representative samples from stockpile and blend of salvaged bituminous material and clean aggregate to material laboratory for trial mix testing. Furnish production results and extraction test results.

Materials Laboratory conducts trial mix testing.

Bituminous Engineer recommends new asphalt cement to be added to each recycled mixture.

Field sample of recycled mixture randomly selected behind the paver for check against lab trial mix. (Optional)

Field sample of recycled mixture selected behind paver for extraction of asphalt cement (one sample per 750 tons or min. of three per day) Avg. of all extractions determines payment for bituminous material for mixture (asphalt cement).

RECYCLING BITUMINOUS SURFACE COURSES

Gordon F. Whitney, P.E.
President

G. J. PAYNE COMPANY

ASPHALT MAINTENANCE ENGINEERS

For Presentation at

ASPHALT CONCRETE RECYCLING SEMINAR

Sponsored by

FEDERAL HIGHWAY ADMINISTRATION

and

CALIFORNIA DEPARTMENT OF TRANSPORTATION

September 15-17, 1981

ABSTRACT

RECYCLING BITUMINOUS SURFACE COURSES

The technology for surface recycling asphalt pavements has been fully developed and is now available to Engineers for more extensive usage on urban and interstate projects. Great improvements have been made in quality control, particularily over the past several years, to eliminate uncertainty and upgrade the end results.

A pavement study to establish a properly budgeted, long range maintenance program is the primary step frequently taken by Public Works Engineers. Corrective procedures may be developed after considering roadway sufficiency, serviceability, structural adequacy and physical conditions of pavement materials.

Surface recycling is selected to correct certain defects. Asphalt pavements exhibiting minor corrugations, alligator cracking, raveling, polished aggregate, or bleeding are all candidates for this strategy. The process consists of passing one or more machine-mounted high intensity heaters over the surface to be repaired at a speed which will allow the distressed material to be softened.

With advanced technology and equipment, pavement temperature is increased slowly, using multiple machines, so that the material is not overheated and a maximum depth is achieved. Chemical additives, called recycling agents, reverse the oxidation process by restoring some of the lost constituents and replasticize the asphalt cement.

The use of seal coats and thin asphalt overlays on pavements that need improved riding qualities and waterproofing can be extended. Surface recycling offers Engineers an ideal way of preparing and rehabilitating pavement sections to a condition where thin overlays can be installed to virtually eliminate reflective cracking and save 25 percent of the cost of new materials. As the cost of asphalt cement escalates and its availability diminishes, the use of surface recycling must be considered in more instances to rehabilitate existing streets.

Introduction

Over the past decade, pavement construction and maintenance costs have more than doubled, while public works budgets have remained relatively constant, sometimes even decreasing. The escalation of highway construction and maintenance costs is a result of our dependence on foreign oil and the direct correlation between asphalt and crude oil product prices. The Engineer has fast become maintenance oriented, as he should be. A major concern must be one of extending the life and serviceability of existing structures, while adhering to the necessity to economize. The more expensive alternate method of restoring a worn flexible pavement by resurfacing is now often revaluated in favor of surface recycling with a thin overlay or a seal coat to waterproof the underlying pavement structure.

The idea of recycling pavements sometimes evokes fears that the recycled material may not possess satisfactory quality and will soon fail under traffic loading. Great improvements have been made in quality control, particularily over the past several years, to eliminate uncertainty and upgrade the end result. Work performed using the new Asphalt Recycling and Reclaiming Association (ARRA) standards(1) coupled with rigid inspection bears little resemblence to earlier heater scarifying work. The technology for successfully recycling asphalt pavements has already been developed and is now available to Engineers for more extensive usage.

Pavement Evaluation

A pavement inventory study to establish a properly budgeted, long range maintenance program is usually the primary step taken. An on-going pavement evaluation program should provide that in each successive year, certain roads previously studied will undergo additional testing. Successive repetitions will permit the establishment of accurate "rates of change" curves. With additional inputs of data, it is possible to accurately program the type, amount and cost of future maintenance, and determine which pavement design, construction method or maintenance technique provides the best economic value.

As might be expected, virtually all roads possess some deficiencies that merit maintenance attention. This maintenance may be of major or minor consequence, but failure to correct a deficiency will lead to further deterioration and increased maintenance costs. Frequently, roads are structurally sound and not in need of an overlay insofar as the pavement thickness. Weathering by the elements can lead to abrading of the surface and reduce serviceability, which can be corrected by proper preventative maintenance.

Many pavements possess highly embrittled asphalt binder and failure to correct this condition will lead to deterioration of the pavement and ultimate structural failure. The asphalt(2) aging phenomenon occurs frequently in the Southwestern United States and is aggravated by the climate, quality of petroleum crude used to produce the asphalt matrix and many other complex reologic and little understood factors.

Corrective procedures may be developed after considering roadway sufficiency, serviceability, structural adequacy and physical condition of pavement materials. Investigations should include deflection testing, field and laboratory testing of pavement and base materials; correlation of field data with historical design and construction information; reviewing maintenance records and traffic loading, and analyzing the information gathered to prepare recommendations[3].

Recommendations vary from immediate routine maintenance to extensive repairs by means of a program of resurfacing, reconstruction seal coating, surface recycling or some combination of these to treat existing surfaces and establish priority schedules for each, based on need, with programmed reviews for updating the priorities. This report will focus primarily upon the maintenance procedures involved in surface recycling.

Historical Recycling Background

The modern surface recycling process evolved from heater planer equipment. Heater scarifying, or remixing, developed by modifying heater planers with scarifier rakes to probe the surface which had been heated. As burner designs continued to improve, machines were able to penetrate a uniform depth up to 2.54 cm or approximately one inch, causing only occasional minor visible emissions.

The basic reason for surface recycling (scarifying and rejuvenating) was to relevel the surface and eliminate the cost of transporting road materials to other locations when it might be utilized on-site. The use of cleaner fuels improved the operating performance of these early machines, although it was a process which had to be closely controlled by the operator when using only one machine.

Surface Recycling Advantages

On certain projects, heater recycling can offer significant improvements to conventional overlays, as well as prepare a surface for receiving thin overlays, chip or slurry seal treatments[4].

- The prime purpose is to develop a low modulus layer of bituminous material with flexibility to retard propagation of cracks.

- A secondary goal is to develop a unitized structure well bonded to produce greater resistance to deflection and shear than would an overlay installed upon a conventional tack coat.

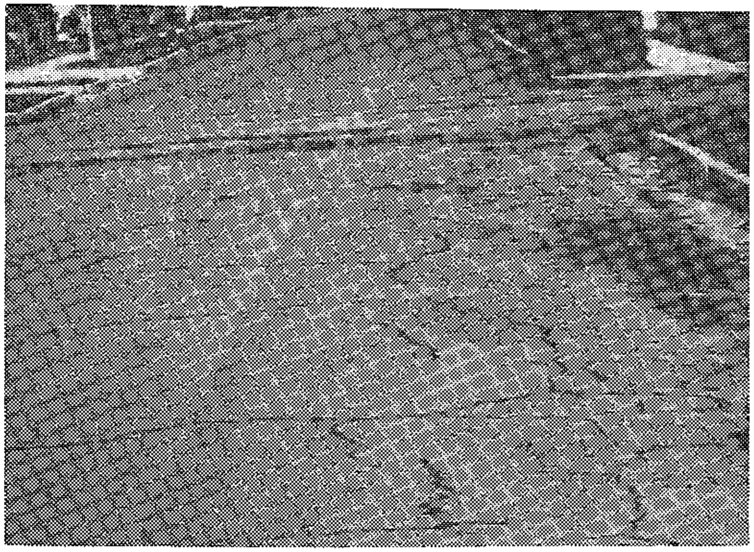
- The heat and re-arrangement of aggregate particles by scarification, breaks the existing surface crack pattern and forms a layer capable of distributing the stress that develops.

- Pavements exhibiting moderate surface distortion are leveled by the scarifier rakes and a vibratory screed to receive a uniform thickness overlay or seal treatment without the need for a separate and costly planing operation.

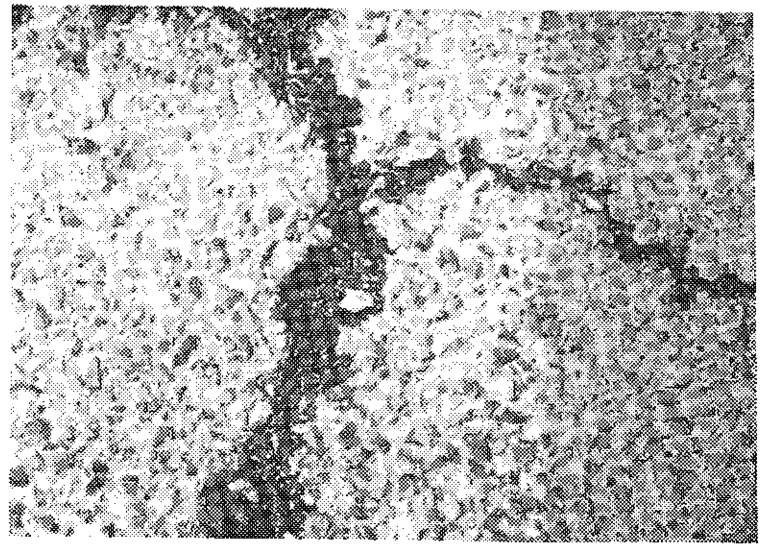
- When surface treatments or thin overlays are programmed, asphalt mix is conserved and drainage capacities of curb and gutter are retained longer. More miles of street may be treated due to low cost of surface recycling.

Analysis

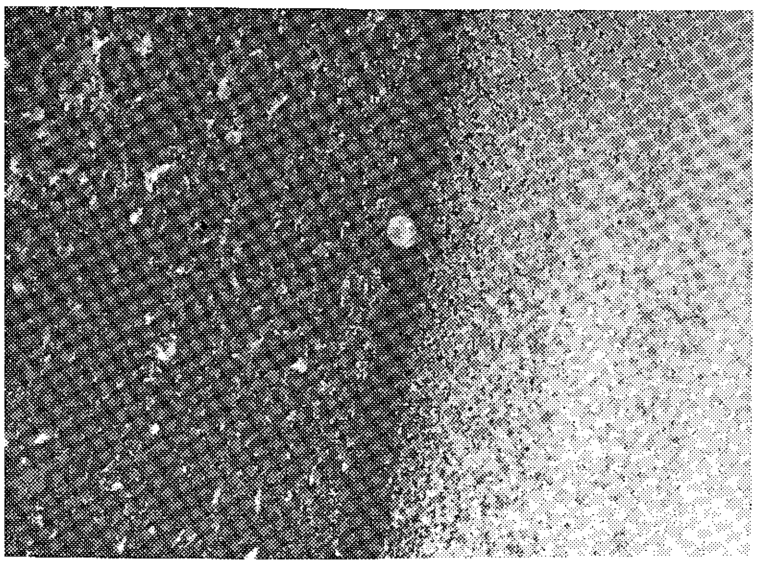
Surface recycling can only correct certain defects. Asphalt pavements exhibiting minor corrugations, alligator cracking, raveling, polished aggregate,



LARGE SHRINKAGE CRACKS FROM EMBRITTLED ASPHALT, ACCUMULATED TRANSMISSION OIL DRIPPINGS AND WATER DETERIORATION AT GUTTER



CLOSEUP OF EMBRITTLED 25 YEAR OLD BITUMINOUS PAVEMENT



LOOSE REMIXED PAVEMENT BEFORE SCREEDING AND COMPACTION AT LEFT WITH 10 LB./SQ. FT. FINISH MAT ON RIGHT

1963 PHOTO OF FATIGUED SECTION (2" AC OVER 8" CRB) WITH RECYCLED SURFACE AND 1" AC BLANKET AT RIGHT, OVERLAY IS STILL IN SERVICE TODAY WITHOUT MAINTENANCE or bleeding are all candidates for the process. On the other hand, if the distress results from an inadequate base and shows up in pavement failure, pot holes, upheaval, or severe rutting, extensive base reconstruction must be considered.

As the technology improved, it was determined that if a pavement temperature is increased slowly, in steps, using multiple machines, the pavement would never reach a temperature to emit particulate. In some instances, cold planing was required to first remove any imperfections or contaminates which have accumulated on an asphalt pavement and which might produce emissions. Environmental Protection Agency standards of maximum permissable limits for emissions may not be exceeded. A current requirement of the South Coast Air Quality District covering the Los Angeles Basin is to be found in the Appendix.

Today's operation for high quality work[5] is monitored by removing a known volume of scarified material to weigh and determine specification compliance. The design engineer can now specify a weight per square decimeter of recycled material just as he would when purchasing a new asphalt concrete material. The recycling agent application is also closely controlled after laboratory tests indicate the type and amount of agent needed to renovate or rejuvenate the asphalt binder. When treating deep lifts of surface recycled material, the loosened mix is generally struck off by a screed, then compacted while still at an elevated temperature and the recycling agent is applied uniformly at the end of the work shift. A thin overlay of new asphalt concrete, or a seal coat, is installed sometime later to complete the process.

Two basic reasons for utilizing surface recycling strategy are:

1. Pavement rehabilitation - here the depth of scarification is of major importance and the Contractor and Engineer should endeavor to achieve the maximum depth of penetration from the rakes. This should be done with care to insure the asphalt cement binder material in the treated layer is not damaged or destroyed by over application of heat.

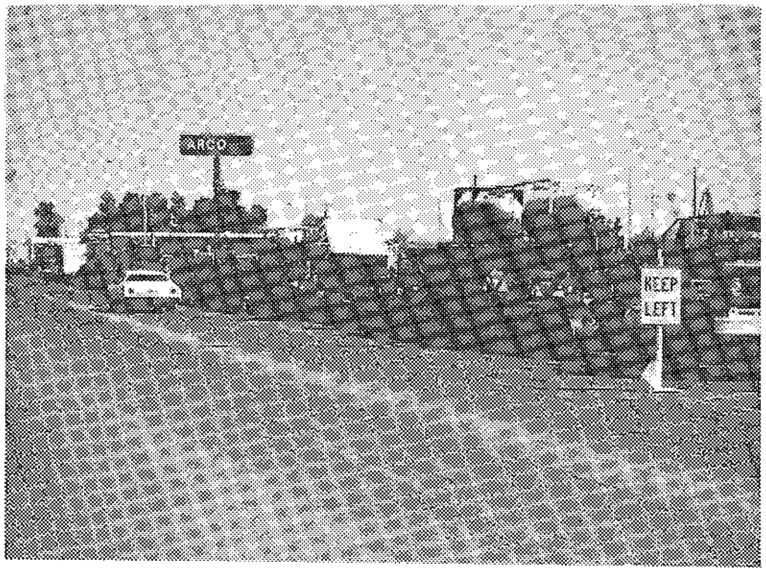
2. Surface preparation for a strengthening overlay - frequently specified for airport and highway construction. Recycling functions to insure the existing surface interface does not possess contaminates, such as paint stripes, fuel and oil drippings or rubber tire impact marks. The necessity for load transfer from the new overlay to the old is extremely important and enhances the structural value of an overlay.

Method of Recycling

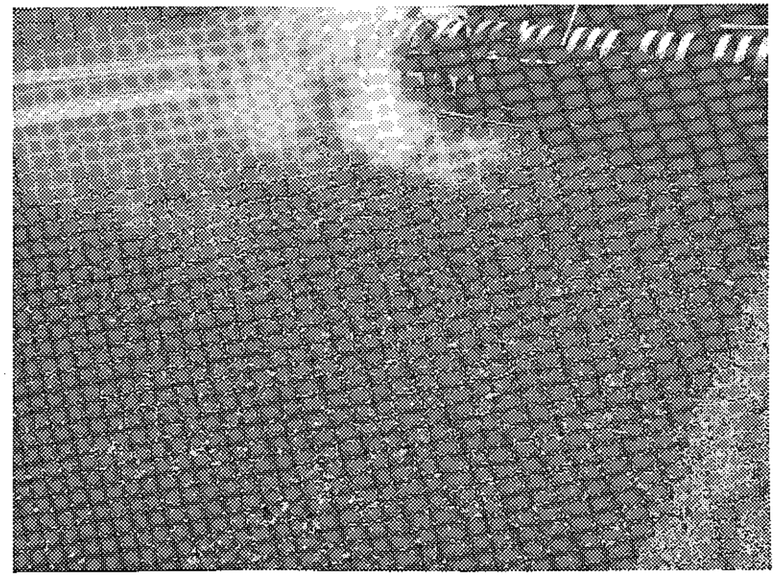
The two stage method is most frequently used. The steps in two stage construction are (1) heat, scarify, compact, apply oil additive, and (2) overlay or seal. Usually there is a delay between surface recycling process and the surface treatment.

- The two stage recycling operation is more economical for each operation and will actually provide a more uniform and better product in the final analysis.

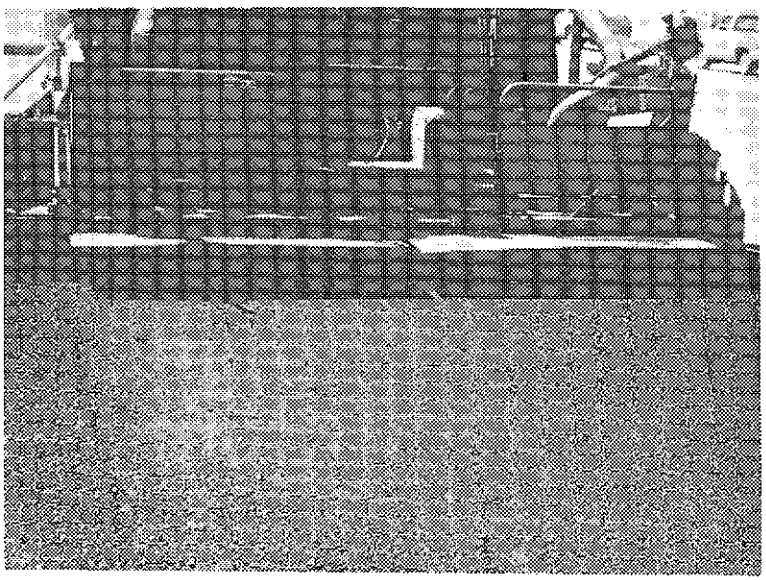
- The inspector viewing surface recycling can measure scarification depth by weighing and control the rate of application of recycling agent.



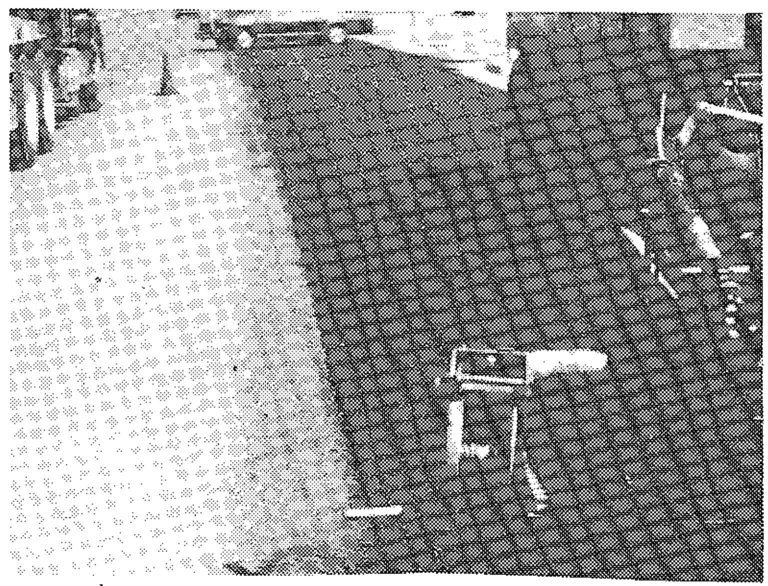
TWO STAGE RECYCLING IN COOLIDGE, ARIZONA, WITH 2 HEATERS - NOTE CLEANLINESS OF OPERATION



CLOSEUP OF RAKE PENETRATION FROM H.D. SCARIFYER ASSEMBLY PRODUCING 1" SURFACE RECYCLING - NOTE SHRINKAGE CRACK AT RIGHT



SCREEDED MATERIAL 9 LB./SQ. FT. AT 270°F PRIOR TO COMPACTION



RUBBER TIRED COMPACTOR FOLLOWS CLOSE TO SCREED

- Density requirements specified by most agencies can be more easily obtained in the two stage operation. A rubber tired compactor is preferred, but a steel roller may be utilized to densify the treated surface and provide compaction immediately following recycling.

- Should the aged condition of the existing asphalt binder warrant a heavy application rate of recycling agent, a delay of several days may be necessary for the agent to be absorbed into the pavement so that bleeding through the overlay or seal treatment is avoided. A uniform application eliminates the distributor marks caused by overspray and laps.

Heating

The process(6) consists of passing one or more machine-mounted high intensity heaters over the surface to be repaired at a speed which will allow the distressed material to be softened. This speed varies widely, depending on several factors. Typical speeds range between 1.5 and 15 m/min (5 to 50 ft/min). The heaters should bring the surface asphalt to a temperature somewhere between 110 to 150°C (230 to 300°F) with the ideal temperature generally in the 125°C (250°F) range during the compaction process. Although much argument and discussion has been directed toward the terms "radiant" and "direct" heating, there is little supporting evidence that any one machine is superior to another in raising pavement temperature. The time of exposure to a constant heat source will cause an elevation of temperature in direct proporation and two machines or more will develop a uniform rise of temperature in the recycled layer without harm to the binder. This time may also be extended by utilizing longer combustion chamber machines.

Care should be exercised to avoid overheating the pavement which may damage the asphalt and also produce undesirable visible emissions. This can be avoided by either reducing the burner combustion heat or increasing the equipment rate of travel. The temperature may be verified or measured by mounding the scarified mix and inserting a thermometer as with conventional new paving material.

Scarifying

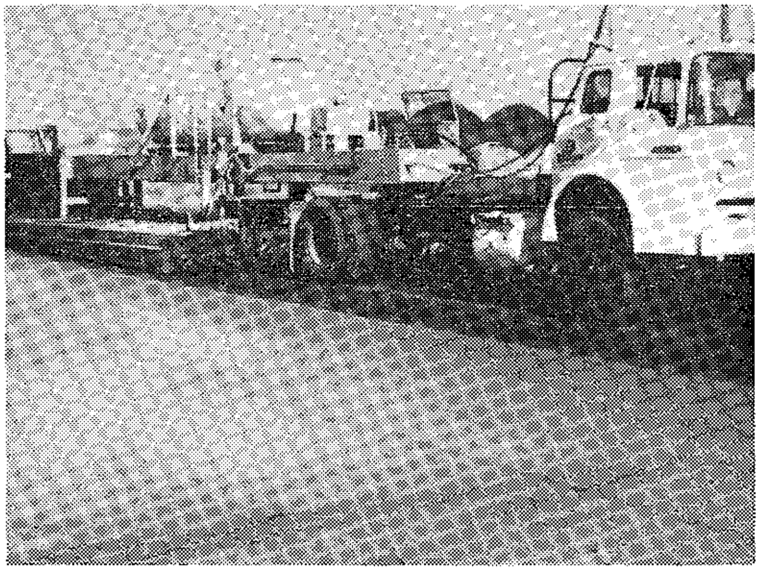
A scarification depth of 1.91 cm or 3/4 inch minimum is recommended; and, as mentioned, for certain types of pavement, multiple heaters may be necessary to allow the heat to penetrate a seal coat. When multiples are used, the first preheats to raise the temperature, while the last machine heats and scarifies the pavement. A screed and roller should follow immediately behind the scarifying machine so that the mix is leveled and compacted at an elevated temperature. The recycling oil is then applied, usually at the end of the working day, insuring a continuous uniform application.

Equipment Improvements

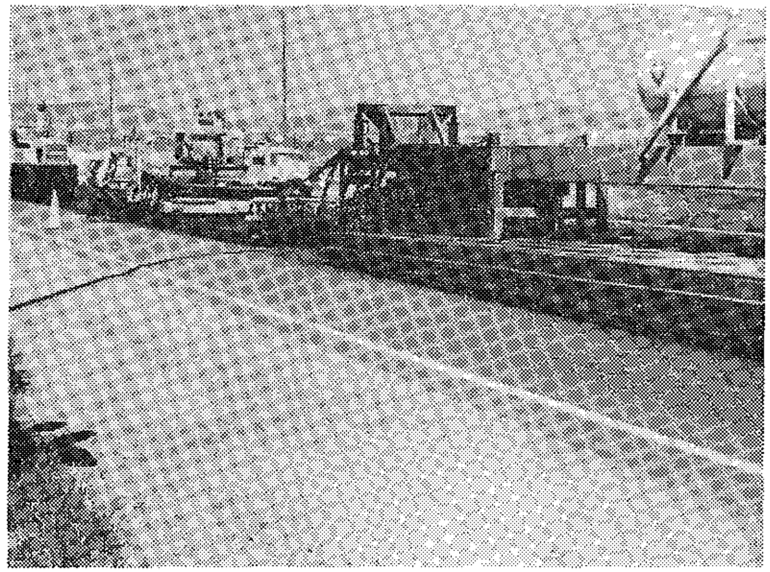
1. Extended length, high reflective combustion chambers 4.86 to 9.12 meters (16-30 feet) insure deeper heat penetration.

2. Improved down pressure on scarifier rakes with stronger rake and tooth assemblies.

3. Heavier power train facilitates scarifying.

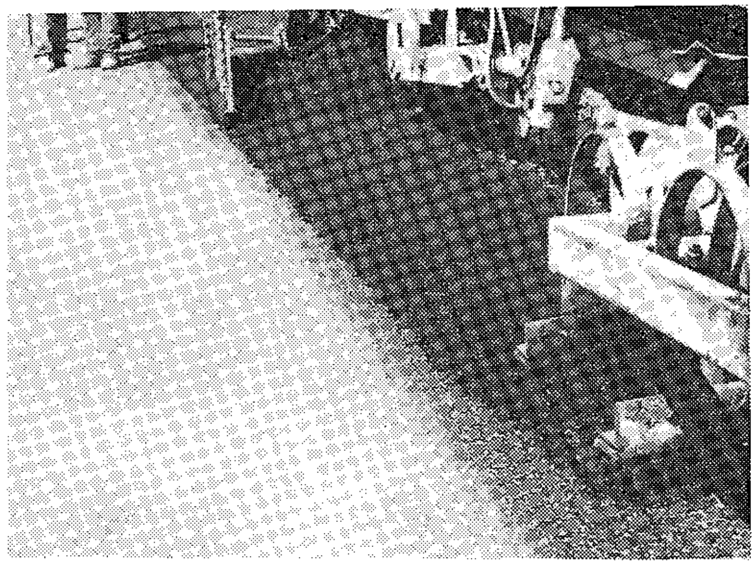


EXTRA LONG (30') FURNACE ON PREHEATER
FACILITATES HEAT TRANSFER

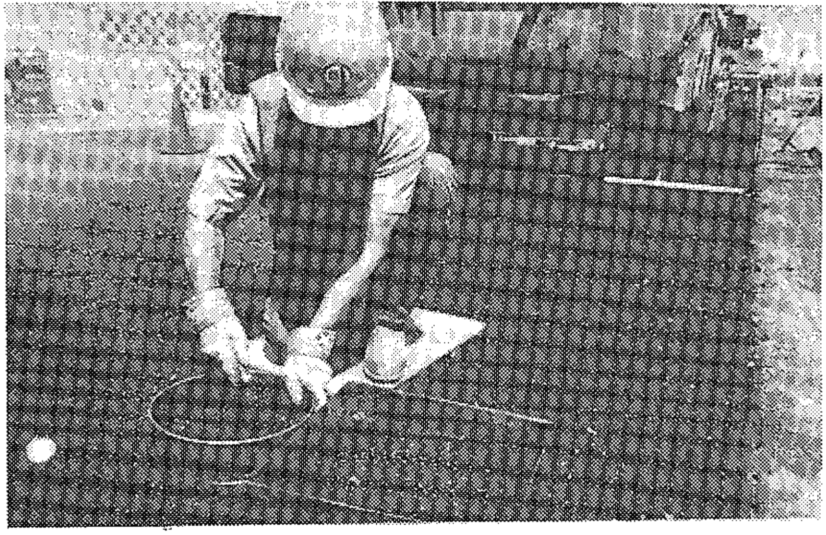


EQUIPMENT TRAIN WITH 2 HEATERS, SCREED
AND ROLLER ON COLORADO DOT PROJECT

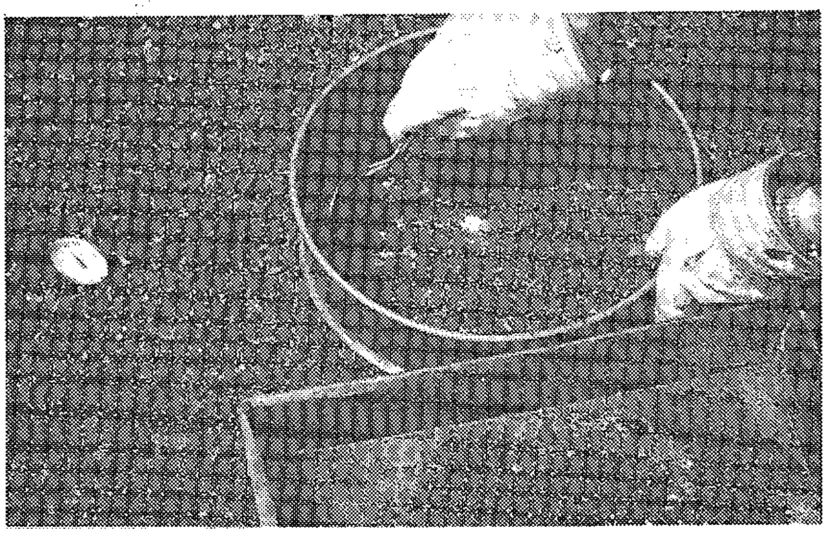
SCARIFYER RAKES PENETRATING 1-½" INTO
AGED HIGHWAY



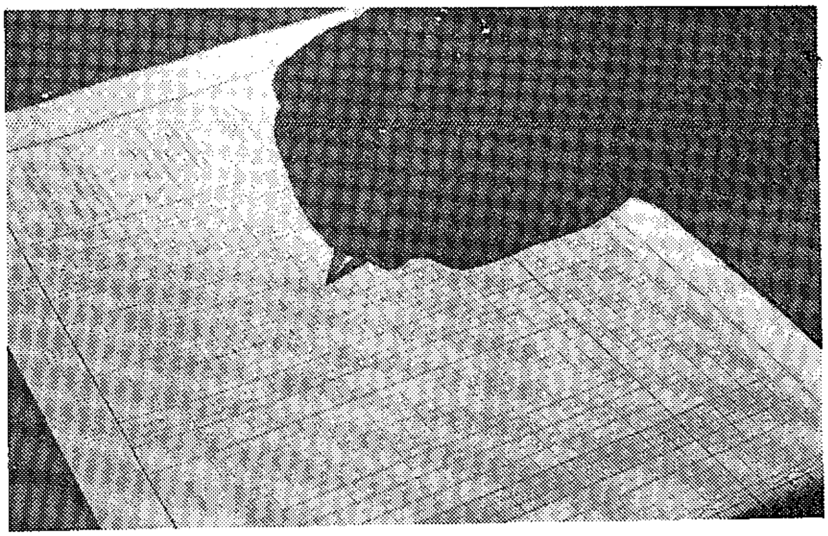
SCREED DISTRIBUTES LOOSENED MATERIAL
LEVELING AND SMOOTHING MIX



INSPECTOR MEASURES TEMPERATURE AND TAKES SAMPLE OF RECYCLED MATERIAL FRONT OF SCREED



CLOSEUP OF MATERIAL AND GRADUATED TEST RING



SAMPLE WEIGHT IS NOTED AND MOVING AVERAGE OF 3 PER HOUR DETERMINES COMPLIANCE

4. Better combustion with Liquified Petroleum Gas (LPG) fuel for cleanliness in lightweight refractory oven.

5. Dual operator controls.

Process Control

Depth of scarification is the real measure of value derived from the surface recycling process. The deeper the scarifier teeth and recycling agent penetrate, the more material is reclaimed to a "like new" condition. Depth of scarification is most equitably controlled by the weight method. A calibrated ring is inserted in the loose scarified material and all material is scooped out and placed in a pan. The material in the pan is then weighed and recorded as pounds of material scarified loose per square foot. Assuming a pavement density of 144 pounds per cubic foot, the scarification meets specifications when nine pounds per square foot is recovered. If pavement density is less than 137 or more than 151 pounds per cubic foot, the weight per square foot requirement is adjusted accordingly.

This control procedure additionally insures the scarified pavement will have sufficient heat for proper compaction. When sufficient heat is provided to enable nine pound scarification, the pavement reaches proper compaction temperatures. The only requirement is that it must be rolled immediately behind the screed while it still holds this heat.

Applying Recycling Agent

The process of pavement aging or oxidation consists of a chemical reaction which slowly changes the characteristics of the asphalt cement. The effect of this change is a gradual embrittlement of the pavement[7]. An oxidized pavement usually appears gray, dried out and dull.

The value created by surface recycling is based on the fact that oxidation occurs most rapidly at the surface, which is in contact with the elements. The surface may have lost some of its resiliency and perhaps has begun to show cracking; while underneath the asphalt binder is relatively unaffected by its environment and in nearly new condition. Studies reported by Coon and Wright[8] indicate no change in relative viscosity of binder below 1.91 cm or 3/4 inch level on pavements 4 to 151 months of age.

Chemical additives, called recycling agents, have been developed which reverse this oxidation process by restoring some of the lost constituents, and in so doing, replasticize the asphalt cement. The agent may be applied at the highest temperature recommended by the refiner to permit even distribution throughout the loosened material. The selection and application of one of these liquids is an important step in surface recycling.

Testing

The amount of recycling agent to be applied to the scarified material layer is determined prior to beginning work. This is done by removing 15 cm (six inch) diameter core samples from the structure for testing in a laboratory[9]. One core is tested as is to determine the viscosity and ductibility of the existing asphalt in the top 1.91 cm or 3/4 inch. The other two are heated, scarified to a depth of 1.91 cm or 3/4 inch, then .45 liter per square meter of recycling agent concentrate equivalent is spread on one core and .9 liter per square meter on the other. These cores are then placed in a 60°C oven for a minimum of three days, after which the asphalt is extracted from the top 1.91 cm or 3/4 inch of each core and tested. The quality selected is mathmatically added to the existing asphalt percentage to determine feasibility of improving the binder qualities without over-asphalting the layer. Regardless of the type of recycling agent used, the same type of test can be performed to first ascertain the lowering of viscosity obtained from using a specific additive and then compare various agents available to treat a hardened asphalt cement. The results must be "fine tuned" by the field inspector when it is apparent that there is a discontinuity in material or that the indicated laboratory amount is causing either a deficiency or excess of oil.

Asphalt Pavement Overlay

After the pretreatment is completed, the asphalt paving operation may proceed at a uniform rate of speed, coordinated with the arrival of trucks to the finishing machine. This is evenly matched with the plant capacity which leads to a higher quality finished surface at a reduced unit paving cost.

If the pavement is open to traffic for a prolonged period before an overlay coat is installed, some caution should be exerted to prevent high speed traffic degradation of the surface. This can be done by signs or a light application of emulsified asphalt on the surface to tighten up the aggregate until the resurfacing or seal treatment is scheduled.

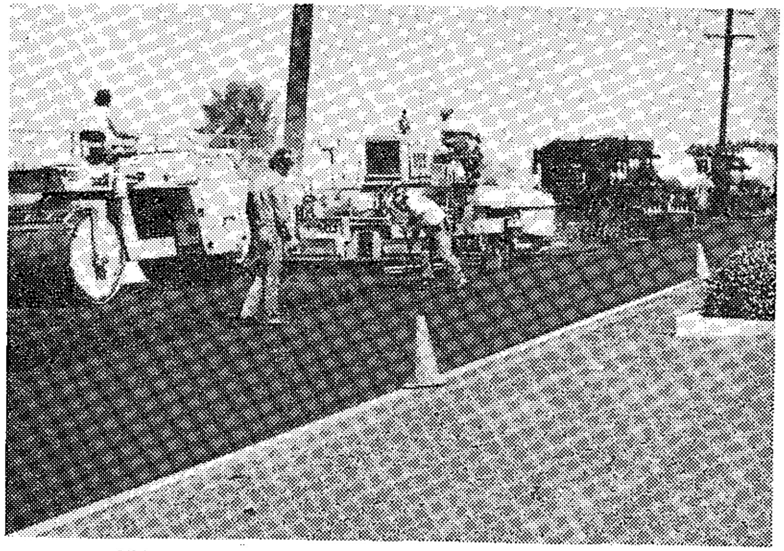
When an overlay is specified, the thickness depends upon the present and future requirements of the structural section. If the goal is to rejuvenate the upper layer of existing material and improve the riding qualities of the street that is structurally adequate, a minimum thickness will suffice. This minimum thickness depends mainly upon the gradation of aggregate in the new mix. As a general guide, the overlay thickness should be not less than 1.5 times the maximum particle size in the new mix.

Crack Prevention

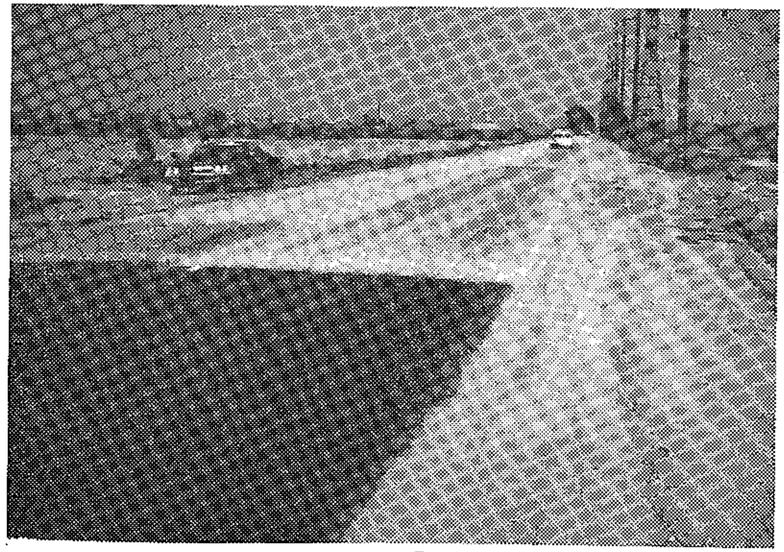
The pavement overlay mix design selected to cover the recycled surface requires consideration of its function. In areas of sparse rainfall where existing pavements show signs of actinic aging, an open graded plant mix is extremely effective. The wide shrinkage cracks common in desert regions due to the drying out of the pavement, render the surfaces rough. During cold weather, wind blown materials often fill the open cracks preventing them from closing during the warm season which causes an extruded bump on either side of the crack. The wind blown material should be removed by blowing with a high pressure air stream prior to recycling. The open graded plant mix fills the crack and the heavier asphalt film on the aggregate keeps the crack from reappearing in the finished surface. This improves the appearance and riding qualities of an otherwise difficult pavement for a much longer duration of time.

Waterproofing Structures

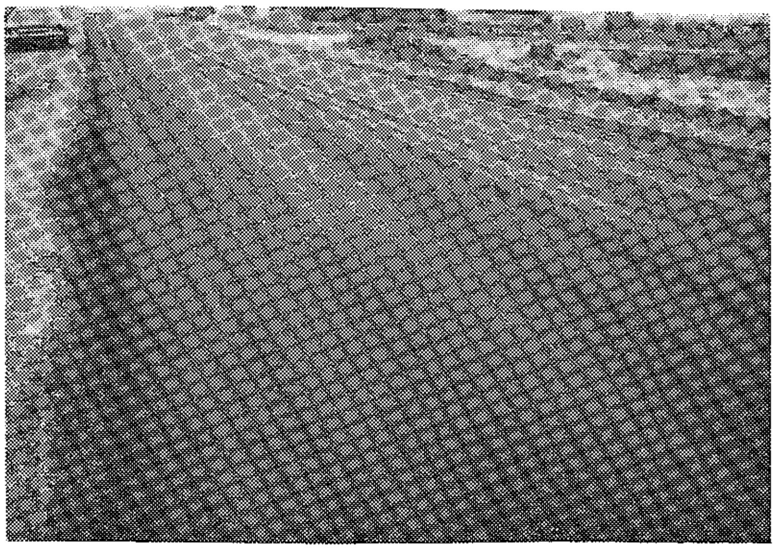
In other sections of the country, a dense graded asphalt plant mix is chosen for its waterproofing qualities to prevent snow and moisture from penetrating the



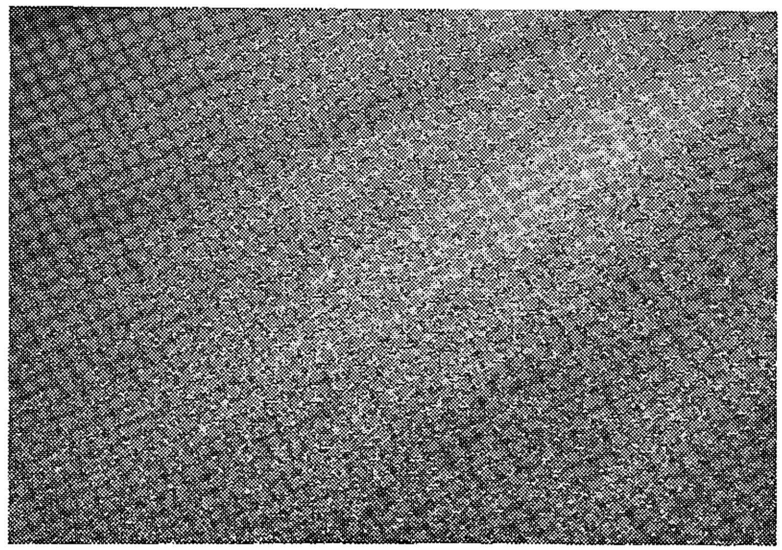
TWO HEATERS, SCREED AND ROLLER PREPARE SURFACE FOR ARMOUR COAT
NOTE: FINISHED LANE ALONGSIDE



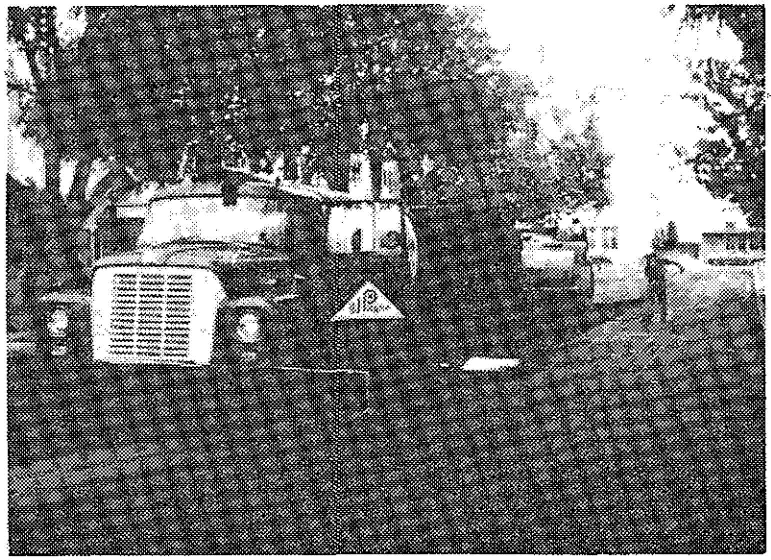
CHIP SEAL WITH UNSEALED CONTROL SECTION IN FOREGROUND



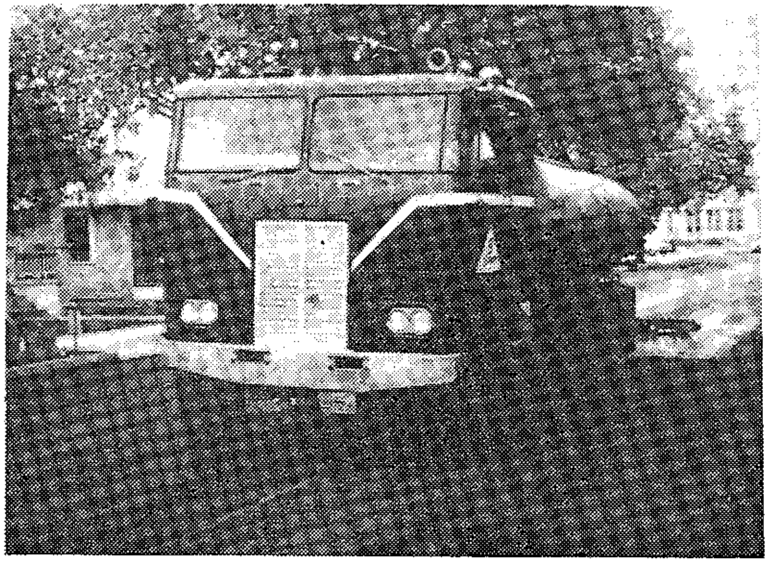
COMPACTED SURFACE AFTER RECLAMITE APPLICATION



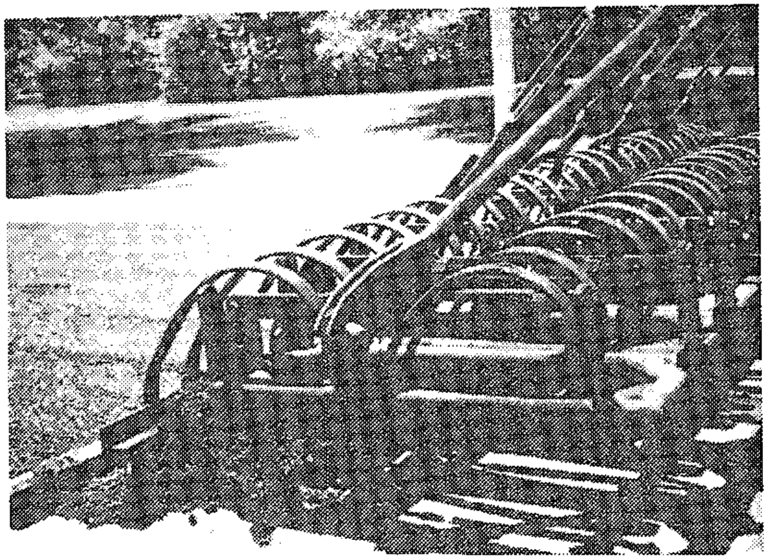
CLOSEUP OF 3/8" MAXIMUM CHIP TREATMENT ON RECYCLED PAVEMENT



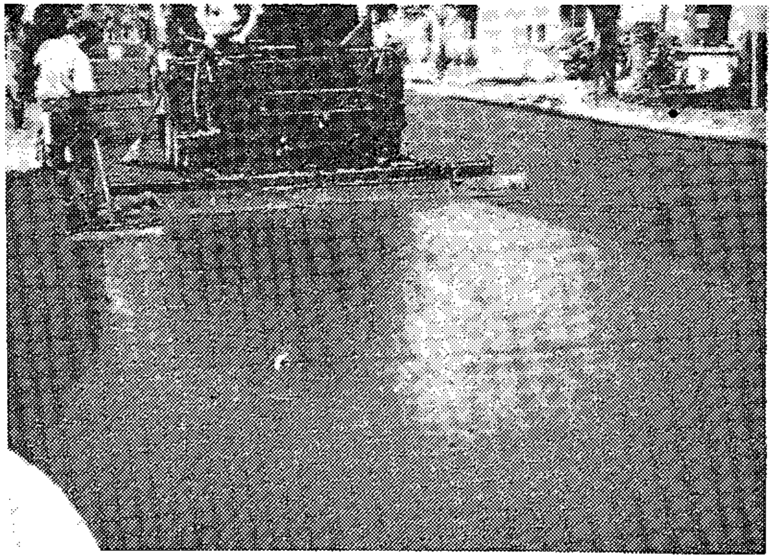
HEATER SCARIFYER, RAKERS AND ROLLER FROM CITY MAINTENANCE PROGRAM



RECYCLING OIL ADDED TO COMPACTED PAVEMENT



CLOSEUP OF RAKES SHOWING LOOSENED MATERIAL AND STRIKE-OFF



SECOND SLURRY COAT APPLIED OVER PRETREATMENT TO FINISH THIS PROJECT subgrade and softening the entire structure. When alligator cracks indicate a diffused or even distribution of stresses in the existing pavement, the addition of a conventional dense graded plant mix overlay will improve the structure and provide years of continuous service with relatively low maintenance cost.

Heavier Load Service

If the primary purpose of resurface/recycling is to increase the structural capacity, the overlay should be designed according to conventional procedures to yield the required strength. While each project must be analyzed for its specific needs and thickness of new asphalt to be placed, it generally is placed at 2.54 cm (one inch), minimum thickness; however, the upper limit can range from 5 to 10 cm, or 2 to 4 inches, depending upon the improvement to the structural section that may be required.

Process Improvements

1. Contaminants or multiple chip seals should be cold planed in advance to allow proper heat transfer to underlaying material.

2. Multiple machines raise temperature in thermal gradients without damaging asphalt binders.

3. Mechanical screeding levels and redistributes material provided by deep scarifying.

4. Compact recycled mix with rubber or steel wheel rollers while temperature remains elevated.

5. Recycling agents available in varieties to suit different pavement conditions are applied after compaction.

6. Two step or "stage" construction permits a lower installation cost for thin overlays.

Conclusion

It is apparent that the use of seal coats and thin asphalt overlays to cover the roads that need improved riding qualities and waterproof flexible structures can be greatly extended. Surface recycling offers Engineers an ideal method to prepare rough pavements to increase the potential for success. Many Western United States Agencies have pioneered the development of higher quality surface recycling to virtually eliminate reflective cracking and save as much as 25 to 30 percent of the cost of new asphalt concrete materials at today's prices. As the cost of asphalt cement escalates and its availability diminishes, the use of surface recycling must be considered in more and more instances to rehabilitate existing pavements.

QUESTIONS MOST OFTEN ASKED ABOUT SURFACE RECYCLING

QUESTION: Do I really have to use a recycling agent?

Not always! There are some special cases where there is adequate asphalt binder in the pavement and the binder still has viscosity and ductility comparable to new asphalt.

However, in most applications, we are treating an age cracked pavement where the asphalt binder has become hard and brittle through the natural aging process. A recycling agent is added (in the correct quality) to bring the asphalt matrix back to properties equal to those originally specified. When this is accomplished, the asphalt cement is restored and the recycled mix will have the quality of virgin hot mix.

A recycling agent provides the most economical method of restoring the aged asphalt to a like new condition. A very small quality does the job because it has only to replace the missing constituents in the aged asphalt.

QUESTION: Can asphalt emulsion or cut back be used as a recycling agent?

The asphalt emulsion does little or nothing to restore the desired properties to aged asphalt binder. Instead, the added asphalt acts as a new binder to hold the aggregate and the old hardened asphalt together. This would be okay if enough emulsion is added and there was a way to mix it. However, more would be required to do the job and the resulting cost would be higher. An over asphalted pavement could result.

QUESTION: Why should I specify a vibrating or oscillating screed as part of the surface recycling equipment train?

The surface recycling process enables you to buy the equivalent of 3/4 inch of hot mix in place at $18.00 per ton or less. A real bargain in face of today's cost of $30.00 per ton or more for new mix in place. The $18.00 per ton cost includes scarification, screeding and compaction followed by a recycling agent.

Scarification to nine pounds provides one and one quarter inch of loose mix which must be leveled and compacted while still hot. It looks and behaves like new asphalt concrete and consequently should be treated in the same manner. You would not think of laying hot mix without specifying a screed. Therefore, it makes good sense to benefit from past experience and specialty equipment which consistently produces quality work.

QUESTION: Why should I specify two heater scarifyer machines instead of a performance oriented specification which requires nine pound scarification?

Two machines operating in tandam versus one will save money and reduce traffic control problems. The explanation is straightforward! Assuming scarification to nine pounds, two machines will complete the job in half the time. This means there will be fewer days expense, i.e., $1,200.00 per day or more for ancillary equipment such as screed, roller, spreader truck, and traffic control. Two machines allow the pavement to be intermittently heated with an appropriate "soaking" time which allows conductive heating between particles. The contractor can achieve specification with two machines with no greater cost of operation per square yard. More important, two machines will provide greater assurance the contractor will be able to achieve nine pound plus scarification, uniformity of temperature, and stay within air quality regulations.

QUESTION: Why should I use the surface "Recycling Process" instead of the older "Train Method" of heater scarification?

Surface recycling is an entirely new process which restores an inch or more of pavement to its original quality and replaces one inch of overlay. It provides eight years of maintenance free life at from 20 to 40 percent savings over alternate maintenance procedures. The earlier "Train Method" of heater scarification was basically a quick surface preparation for an overlay. It did improve bonding of the new overlay. However, the heat penetration and depth of scarification was limited and, consequently, there was insufficient loosened recycled material to warrant leveling and compaction. It was most appropriate to follow this surface preparation with an immediate overlay.

Since surface recycling replaces an inch of overlay instead of only preleveling the surface, the economic benefits are much greater. There is an inch and one quarter of loose hot mix to work with which dictates redistribution with an occilating or vibratory screed. This eliminates the need for leveling with costly new hot mix but requires immediate compaction treatment with a pneumatic roller. The pavement is then treated with a recycling agent and opened to traffic. The wearing course is applied several days or several weeks later.

Usually, the surface recycling equipment train moves at a much slower speed than a paver applying a thin overlay. Consequently, both processes can operate at optimum efficiency when working separately. Traffic control is more easily handled when the processes are separated. Inspection, quality control and traffic control are readily accomplished when the processes are separated.

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2. G. Way, "Asphalt Properties and Their Relationship to Pavement Performance in Arizona", AAPT, Lake Buena Vista, Florida, February 1978

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4. G. F. Whitney, "Thin Overlays and Special Applications", Symposium on Urban Paving Problems - MCAI, Washington, D.C., January 13-17, 1969

5. R. J. Peters, "Surface Recycling - Quality Control", Asphalt Recycling and Reclaiming Association, Palm Springs, California, March 1980

6. Asphalt Institute MISC 77-3 June 1977, "Surface Recycling of Asphalt Pavements by the Heater Overlay Process"

7. D. D. Davidson, William Canessa and S. J. Escobar, "Practical Aspects of Reconstituting Deteriorated Bituminous Pavements", 1979 American Society of Testing Materials

8. R. F. Coons and Paul H. Wright, "An Investigation of the Hardening of Asphalt Recovered from Pavement of Various Ages", Proceedings of the Association of Asphalt Paving Technologists, Volume 37, 1978, Page 510

9. William Canessa, "Reclamite's Function with the Heater Scarifyer", Fifth Annual Texas Public Works Short Course, Texas A & M, College Station, Texas, February 23-25, 1976

APPENDIX

A. Suggested Surface Recycling Guide Specification

B. South Coast Air Quality District Rule 1120

BID SPECIFICATIONS
FOR
SURFACE RECYCLING

SCOPE

The work covered by this section of the specifications consist of furnishing all labor, equipment and materials and performing all operations in connection with heating, scarifying, leveling, compacting, and applying a recycling agent preparatory to receiving an asphalt concrete overlay.

CLEANING

Prior to commencing heater scarifying operations, the pavement shall be cleaned of all loose material. Power brooms shall be supplemented when necessary by hand brooming and such other tools as required to bring the surface to a clean suitable condition, free of deleterious material. Any required patching work shall be completed prior to beginning the process.

EQUIPMENT

1) The equipment used to heat and scarify asphalt surface shall be fueled by liquified petroleum gas. It shall fully meet the standards of the State and Local Bureau of Air Pollution Control. The combustion chamber shall be insulated, rear wheel positioned and equipped with burners rated at a minimum of 15,000,000 BTU's per hour. The machine shall be equipped with two rows of spring-equalized scarifier leveling rakes, removable teeth incorporating an automatic release for manhole and valve protection. A competent operating crew, including a service vehicle shall be provided.

2) The equipment used to distribute and level the scarified material shall be approved paving machine equipped with an operating vibratory or oscillating heated screed. The machine must be capable of screeding the full width of scarified material. A competent operating crew shall be provided.

3) One twelve (12) ton or greater pneumatic-tired roller and operator shall be furnished to compact the scarified material. The contractor may furnish another type compactor of equal size if approved by the engineer.

4) One asphalt, cab-controlled, liquid spreader with operator shall be furnished to distribute the asphalt recycling agent.

CONSTRUCTION DETAILS

A minimum of two heater units will be utilized in tandem so that the heat emitted and the rate of travel will achieve specified requirements. The number of additional heater units shall be determined by the contractor; however, only the scarifier rakes on the final heater unit of the series shall scarify. A minimum production of 1,200 square yards per hour shall be required.

The existing asphalt surface shall be heated from 6 to 12 inches wider than the width to be processed. The temperature of the scarified material shall be 300°F maximum when measured with a stick thermometer behind the scarifier.

The weight of existing asphalt surface has been estimated to be approximately 144 pounds per cubic foot. On this basis, a minimum of nine pounds per square foot of existing surface shall be scarified to obtain a depth of between 3/4 and 1 inch. If tests indicate that the material weighs either less than 137 or more than 151 pounds per cubic foot, the weight per square foot requirement will be adjusted accordingly by the engineer.

The scarified material shall be distributed and leveled only the width processed and be rolled immediately while it possesses sufficient heat to be properly compacted. As soon as possible, but no more than eight hours after compaction, an asphalt recycling agent selected from below shall be applied undiluted. The rate of application shall be determined by the engineer, based on pre-construction laboratory analysis and adjustments for varying field conditions.

TESTING AND CONTROL

The bidding agency will employ the services of a qualified laboratory to obtain the following data. Abson recovery tests shall be made on representative cores prior to construction to obtain asphalt penetration (ASTM D-5) and to determine results of treating binder with varying quantities and grades of recycling agents per the following specifications. No work shall be undertaken until the laboratory report has been approved by the Engineer. The cost of testing and preparation of reports shall be included in the cost per square yard for surface recycling. The number of cores required shall not exceed one (1) per 10,000 square yards of treated pavement.

ASPHALT RECYCLING AGENTS

The asphalt recycling agent shall be composed of a petroleum base oil uniformly emulsified with water and shall conform to the following physical and chemical requirements.

	Test Method		Requirements			
			Light Grade (Reclamite)		Medium Grade (Cyclogen ME)	
	ASTM	AASHTO	Min.	Max.	Min.	Max.
Tests on Emulsion						
Viscosity @ 77°F, SFS	D244-77	T59-74	15	85	15	85
Residue, %	D244-77(Mod)[1]	T59-74(Mod)[1]	60	--	60	--
Cement Mixing Test, %	D244-77	T59-74	--	2.0	--	2.0
Sieve Test, %	D244-77(Mod)[2]	T59-74(Mod)[2]	--	0.1	--	0.1
Particle Charge Test	D244-77	T59-74	Positive		Positive	
Tests on Base Oil[3]						
Original						
Viscosity @ 140°F, cSt	D2170-76	T201-74	80	500	1000	4000
Flash Point, COC, °F	D92-78	T48-74	400	--	450	--
Saturates, %[4]	D2007-75	---	--	30	--	28
Asphaltenes, %	D2006-70	---	--	1.5	--	9.0
PC/S Ratio[5]	D2006-70	---	0.5	--	0.5	--
Maltenes Distribution Ratio $(PC + A_1)/(S + A_2)$[5]	D2006-70	---	0.2	1.0	0.2	1.2
Test on Residue From RTF-C Oven Test @ 325°F	D2872-77	T240-73				
Viscosity Ratio[6]	D2170-76	T201-74	--	3.0		2.5
RTF-C Oven Wt. Change, %	D2872-77	T240-73	--	6.5		2.0

1 ASTM D244 Modified Evaporation Test for percent residue is made by heating 50 gram sample to 300°F until foaming ceases, then cool immediately and calculate results.

2 Test procedure identical with ASTM D244 except that distilled water shall be used in place of 2% sodium oleate solution.

3 Values obtained on the emulsion's residue may vary slightly from the base oil.

4 ASTM D2006-70 can be used for the determination of saturates.

5 In the Maltenes Distribution Ratio Test by ASTM Method D2006-70

PC = Polar Compounds $\quad$ A_1 = First Acidaffins

A_2 = Second Acidaffins $\quad$ S = Saturates

6 Viscosity Ratio = $\dfrac{\text{RTF-C Viscosity @ 140°F, cSt}}{\text{Original Viscosity @ 140°F, cSt}}$

PROTECTION OF EXISTING IMPROVEMENTS

Since high temperatures are required in the surface recycling operation, Contractor shall exercise care against possible injury or damage to existing improvements. Contractor shall protect all existing curbs, gutters, trees, shrubbery and other improvements from damage. The smaller parkway trees shall be protected by shields and overhanging trees may be sprayed with water to inhibit damage. No machine with an open flame exhaust will be permitted. Existing improvements damaged by the Contractor shall be repaired or replaced to the satisfaction of the City Engineer at no cost to the City.

AIR QUALITY PRESERVATION

Contractor shall minimize the escaping of solids into the air by either the machine or burning of pavement during the operation. The machine shall be operated under a permit of the local Air Quality Control District. In the event that an emission problem develops, it may be necessary to remove the contaminate by cold planing. No additional compensation will be allowed for any steps required to reduce emissions.

MEASUREMENT AND PAYMENT

Cost of pretreatment, including cleaning, heating, scarifying, leveling and compacting, but excluding recycling agent, shall be paid for in square yards of surface area covered regardless of the number of operations involved to meet these specifications.

Asphalt recycling agent paid for by weight shall be weighed on sealed scales, regularly inspected by State Bureau of Weights and Measures, or may be measured in some other approved manner. A load slip shall be furnished for each vehicle weighed and slip shall be delivered to the Engineer at point of delivery of material. Asphalt concrete overlay required shall not be paid for under this section.

South Coast
AIR QUALITY MANAGEMENT DISTRICT
DISTRICT HEADQUARTERS
9420 TELSTAR AVENUE, EL MONTE, CALIFORNIA 91731 • (213) 443-3931

RULE 1120 - ASPHALT PAVEMENT HEATERS

(adopted August 4, 1978)

A person shall not operate an asphalt pavement surface heater or an asphalt heater-remixer for the purpose of maintaining, reconditioning, reconstructing or removing asphalt pavement unless all of the following requirements are met:

a) Black or gray smoke emissions of more than 60 consecutive seconds duration shall not be discharged to the atmosphere and in aggregate, black or gray smoke emissions shall not exceed a total of three minutes in any one hour of heater operation. For the purpose of this rule, black or gray smoke is to be viewed by an observer at the point of greatest opacity.

b) Visible emissions of more than 40% opacity, other than black or gray smoke, shall not be discharged to the atmosphere for a period or periods totalling more than three minutes in any one hour. For the purpose of this rule, visible emissions are to be viewed by an observer at a point no lwer than 36 inches above the pavement.

c) All units of equipment are fired with gaseous fuels that do not contain in excess of 80 ppm by volume of sulfur compounds calculated as H_2S, or with diesel fuels that do not contain more sulfur than specified by the California Air Resources Board.

d) Grease, crack pouring materials or oily substances that burn or produce smoke are removed by mechanical grinding, by cold planing or by other mechanical means prior to the use of the heating equipment on the contaimінated area.

e) Asphalt pavement at the work site is cleared of paper, wood, vegetation and other compustible refuse prior to operation of the heating equipment.

f) The Executive Officer is notified of an operation using pavement heaters within 10 days after a contract is signed authorizing such work and again, at least 24 hours before an operation starts. Each notification shall describe the location, estimated starting time and an estimate of the time to complete the work.

g) The equipment is operated only during days on which open burning is allowed. However, an operation that begins on a day when open burning is allowed, may be continued on successive days whether open burning is allowed or not allowed. Information concerning whether a proposed operating day meets the criteria specified in this subparagraph (g) may be obtained from the Executive Officer or his authorized representative.

COLD RECYCLING EQUIPMENT

by

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ENGINEERING CONFERENCE ON RECYCLING

ASPHALT AND CONCRETE PAVEMENTS

UNIVERSITY OF MICHIGAN

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COLD RECYCLING DEFINITIONS

Cold Mix Asphalt Pavement Recycling - - The re-use of the entire existing pavement structure including, in some cases, the underlying untreated base material. The processing can be either in place or processed at a central plant. The materia's are mixed cold and can be reused as an aggregate base, or an asphalt base with the addition of asphalt or other additives.

In Place Cold Recycling - - Pulverizing the pavement section, Adding and mixing stabilizers, Fine Grading, Compaction, and Curing. All Work is done on the grade without any transport of the subject materials.

Central Plant Recycling - - After pulverization the adding and mixing operations are completed in a central plant in lieu of traveling type mixers. The subsequent fine grading, compaction and curing are still the same.

Puliverization - - The breaking up and sizing of the material to be recycled.

EQUIPMENT FOR COLD RECYCLING

GENERAL: There are available a number of different types of machines to accomplish Cold Recycling. A review of the various types of crushing, mixing, spreading, and compacting equipment is presented in this chapter.

CRUSHING EQUIPMENT

1. Grid Rollers:

   a roller with open mesh # with 2" to 4" openings, normally used to reduce scarified seal coats and thin plant mix asphalt 1" to 1½".

2. Impact-Ripper, Cutter, Crusher:

   an impact roller used on a grader blade or with rear scarifiers normally used to reduce seal coats and thin plant mixed asphalt 1" to 2". Also used to reduce thick plant mixed asphalt 3" to 6" so it can be further reduced using a hammer-mill.

3. Hammer-Mills:

   either tow type or self-propelled can reduce most asphalt materials from seal coat to 6" + plant mix. It is also used as a rock crusher handling stone to 18" diameter. It can reduce these materials to 2" - material.

4. Roto-Mills:

   these machines can reduce all asphalt plant mixed materials to a depth of 6" to 8" and reduce this material to a one to 1" ½.

Regardless of the type of equipment used, the following end result spec could be used as a guide line:

When the use of Crushing equipment is specified in the proposal the equipment shall be approved by the engineer. The machine shall be of a type designed by the manufacturer specifically for reduction of pavement material, in-place and be capable of reducing the pavement material to the specified sizes. The material must pass a 2" screen, except that 5% oversize will be allowed as long as it is not detrimental to the job.

MIXING EQUIPMENT

TRAVEL PLANTS: Travel plants are self-propelled pug-mill plants that proportion and mix aggregates and asphalt as they move along the road. There are two general types of travel plants:

1. One that moves through a prepared aggregate windrow on the roadbed, adds and mixes the asphalt as it goes and discharges to the rear a mixed windrow ready for aeration and spreading.

2. One that receives aggregate into its hopper from haul trucks, rotomills, or windrow pick-up machines, adds and mixes asphalt and spreads the mix to the rear as it moves along the roadbed (see attached pictures 1 & 2).

Certain features and performance capabilities are common to all travel plants, enabling them to operate effectively and to produce a mix metting design and specification criteria. To begin, the tracks or wheels on which the machine moves must be so sized, designed and positioned that they do not damage or rut the surface on which it operates when the plant is fully loaded. The basic purpose of the travel plant is to mix asphalt and aggregate. Some machines are equipped with devices that maintain the proper proportions automatically. Others, however, require that a uniform speed be maintained to ensure uniform proportioning. Regardless of the type, the manufacturer's recommended procedures for calibrating and operating the travel plant should be followed carefully. Finally, the efficient travel plant should be capable of thoroughly mixing the asphalt and aggregates, uniformly dispersing the asphalt and adequately coating the aggregate particles, thus producing a mixture that is uniform in color.

Hopper type travel plants, and in some cases, windrow plants, require devices for ensuring accurate control of the flow of aggregates from the hopper to the pugmill so that correct mix proportions are maintained. Feed of asphalt to the pugmill similarly requires accurate calibration. Typically, a positive displacement pump is necessary to deliver asphalt to the mixing chamber via a spray bar.

ROTARY-TYPE MIXERS:

1. Multi-Shaft: (Pic. 1 & 2)

Multi shaft mixers are so designed to:

1. cut in-place material to the proper depth
2. remove this material from the road bed and pass it through a liquid asphalt spray
3. to blend this material and asphalt to a consistant mix

This machine has a positive displacement pump that is controlled by the foreward speed of the machine and a meter to determine the proper amount of liquid being distributed.

2. Single-Shaft Mixers:

a. <u>clockwise rotation</u> (Pic. 1)

a single shaft mixer that cuts down and puts material in front of the shaft so it is continuously remixed. Can be fitted to have a built in asphalt feeding system or can be used behind an asphalt distributor. Has good mixing ability but positive depth control can be a problem.*

b. <u>counter clockwise</u> (Pic. 2)

although the up-cut single shaft mixer uses less power the material does not remain in the mixing chamber as long as the clockwise machines, therefore, it can take more passes to get a satisfactory mix. These machines can also be fitted to have a built in asphalt feeding system or can be used behind an asphalt distributor. Again positive depth control is a problem.*

* Positive depth control is a problem because after the first pass the material; i.e. gravel, is in a fluffed position and the weight of the machine and additional passes will either raise up on this material requiring more depth or compact this material too much requiring less depth.

Both types of machine have the common capability of effecting a smooth bottom cut and then blending the material with asphalt into the mixture specified. But each type individually is marked by certain devices and features that enable it to perform. Machines with built-in asphalt feeding must have the capability for accurate metering and blending of asphalt into the in-place materials in synchronization with a continuous forward movement. Furthermore, they must have spray bars that will distribute the liquid uniformly across the mixer's width. They must be equipped with controls for both depth of cutting and processing and for spreading the mixed material being laid out behind.

Rotary mixers without asphalt spraying equipment generally feature controls that permit adjustment of cutting depth to at least 25 cm (10 inch) adjustment of tail board, and adjustment of the hood itself for aeration purposes.

MOTOR GRADERS: Blade mixing is the on-site mixing of asphalt and in-place materials on the roadbed by a motor grader. The asphalt is applied directly ahead of the motor grader by an asphalt distributor.

For most effective blade mixing, the motor grader should have a blade at least 3 m (10 ft) long, and should have a wheelbase of at least 4.5 m (15 ft). Motor graders used for final layout and finishing of the surface should be equipped with smooth, rather than treaded, pneumatic tires. Scarifier or plow attachments may be mounted before, behind, or both before and behind the blade.

ASPHALT DISTRIBUTOR: The asphalt distributor is a key piece of equipment in cold mix construction, particularly when rotary mixers without built-in asphalt feed are used, or when blade mixing is utilized. The asphalt distributor, either truck, or trailer-mounted, consists of an insulated tank, self-contained heating system, a positive displacement pump, and a spray bar and nozzles through which the liquid asphalt is applied under pressure on to the prepared aggregate materials.

Asphalt distributors range in performance and capability, with some capable of spreading up to 4.5 m (15 ft) at controlled rates to as high as 13.5 litre/m2 (3 gal/yd2).

It is important to keep an adequate supply of asphalt at or near the jobsite to avoid delays. In rural areas, it may be advisable to have an asphalt supply truck at the project.

WINDROW SIZERS: In roadbuilding, a windrow is a long, narrow bank of uncompacted material on the roadbed, shaped to size with a spreader box, windrow sizer, proportioning windrow box, or a motor grader. If cold mixes are to be prepared by road mixing, accurately sized windrows are essential to ensure that the required thickness of pavement is constructed without resorting to spotting, picking up, or otherwise shifting the mixture.

SPREADING EQUIPMENT

MOTOR GRADER: When a motor grader is used to spread asphalt cold mix, it should be checked carefully before putting it into service.

The cutting edge of the blade should be sharp and must be straight from end to end to produce the required cross section. The blade should be long enough to ensure finishing to close transverse tolerances. Usually, 3.7 or 4 m (12 or 13 ft) blade is used.

The joints and linkage of the blade suspension system should be snug and free from excessive wear. Otherwise, the blade may vibrate or allow irregular pressure during operation and result in surface irregularities. Also, the mold board and circle gear may settle when the machine stops or they may climb while spreading.

The motor grader should be heavy enough to hold the blade firmly and uniformly on the surface while spreading the mixture. The wheelbase should be long enough to permit planing to close tolerance. On surface courses, the tires should have smooth treads to keep from leaving lug marks in the pavement. And the engine should be powerful enough to propel the machine without straining when spreading the mixture.

Automatic controls that hold the blade to a set transverse slope regardless of vertical movements of the grader wheels are available.

TRAVEL PLANTS: Automatically spread to proper grade and cross section.

AUTO GRADER: (Pic. 1) can either spread directly from the existing grade or from a windrow.

PAVERS: When equipped with a windrow loader can also be used to spread from a windrow.

GRAVEL SPREADERS: that attach to bull dozers or graders can be used to spread windrows.

COMPACTING EQUIPMENT

PNEUMATIC-TIRED ROLLERS: Pneumatic-tired rollers used for compacting cold mixes should be the self-propelled tandem type. They can have two to seven wheels in front, four to eight in rear, and the wheels should be free to oscillate vertically. They range in weight from 2.7 tonnes (3 tons) empty to 32 tonnes (35 tons) with wet sand ballast.

A pneumatic-tired roller's weight, by itself, is but one factor in its compaction effectiveness. Other factors that affect ground pressures are wheel loads, inflation pressure, and contact area of the tire.

Smooth tires should be used on the roller as treaded tires may leave tread marks that cannot be removed by the final rolling. The contact area of the tire may be adjusted for a given wheel load by increasing the inflation pressure; or it may be adjusted by leaving the inflation pressure unchanged and increasing or decreasing the wheel load. The inflation pressure of the tires usually will be specified with these pressures maintained within +/- 34 kPa (+/- 5 psi).

STEEL-TIRED ROLLERS: There are two basic types of steel-tired rollers:

1. Three-wheel rollers, equipped with two drive wheels, usually 150 to 180 cm (60 to 70 in.) in diameter by 50 to 60 cm (20 to 24 in.) wide, and a steering roll, smaller in diameter, but wider. Weights vary from 7.2 tonnes (8 tons) up to 14.5 tonnes (16 tons). Some steel-tired rollers have wheels to which ballast may be added to increase effective weight.

2. Tandem Rollers, two-axle, available in weights ranging from 2.7 to 13.6 tonnes (3 to 15 tons) or more. They generally have ballastable wheels. Although portable tandems are available, with weights in the 2.7 to 5.4 tonne (3 to 6 ton) range, most projects require rollers of 7.2 tonnes (8 tons). Generally, weight exerted by the rear roll should be not less than 438 N/cm (250 lb./in.) of roll width.

VIBRATORY ROLLERS: Vibratory rollers are made with one or two smooth-surfaced steel wheels 90 to 150 cm (36 to 60 in.) in diameter and 120 to 245 cm (48 to 96 in.) in width. These rollers compact by a combination of static weight and dynamic force, with the frequency and amplitude of the force being adjustable. Usually, high frequencies are desirable for asphalt mixes. Both the amplitude and frequency are varied for the particular mix being compacted. In many cases, the best combination is determined on field test panels prior to construction. Vibratory rollers should be equipped with a drum-wetting system and a power hydraulic steering system. If a single drum vibratory roller is to be used it should have smooth tires and both the drum and the tires should have a wetting system.

CONSTRUCTION PROCEDURES

1. CRUSHING.

When the use of crushing equipment is required, the equipment shall be an approved rotary reduction machine having positive depth control adjustments in increments of one-half inch and be capable of reducing material which is at least six inches in thickness. The machine shall be of a type designed by the manufacturer specifically for reduction in size of pavement material to the specified size. The cutting drum shall be enclosed and shall have a sprinkling system around the reduction chamber for pollution control. The rate of foreward speed must be positively controlled in order to assure consistent size of reduced material. The machine should be equipped with an accurate tachometer which is mounted in full view of the operator. The crushing equipment shall meet the approval of the engineer. The material to be recycled shall be scarified and uniformly crushed to a maximum size of 2", except that 5% of the material is not so large as to adversely affect the stability and structural integrity of the mixture nor hamper the shaping operations.

Crushing Equipment:

1. Grid Rollers: Normally used to reduce seal coat and thin asphalt mats 1" to 1½". Will reduce only to approx. 2" size.
2. Ripper, Cutter, Crushers: Normally used to reduce seal coats and thin plant mixed asphalt 1" to 1½". Can also be used to reduce plant mix asphalt for further reduction with a hammer-mill.
3. Hammer-Mills: Can reduce most asphalt materials from seal coat to 6" depth plant mix asphalt, to -1" material.
4. Roto-Mills: Can reduce all asphalt materials to pass a -1" graduation.

Mixing Equipment:

a. Blade Mixing.

b. Travel Plants.

1. Windrow Mixers

2. Removed Material Mixers

c. Rotary-Type Mixers.

1. Multi-shaft Mixers

2. Single shaft
   a. Clockwise Rotation

   b. Counter Clockwise Rotation

The material shall be crushed in one or more passes to the depth specified on the plans or in the proposal. The maximum length or width of roadbed to be crushed at any one time shall be as directed by the engineer. Normally this will be the amount that can be recycled in one day.

WINDROWS: Several types of cold-mix construction require that the aggregates be placed in windrows prior to mixing and spreading. If windrows are to be used, the roadway must be cleared of all vegetation to a width sufficient to accommodate both windrow and traffic while the mixture cures. Because the thickness of the new pavement is directly proportional to the amount of aggregate in the windrow(s), accurate control and measurement of the volume of the windrowed material is neces

Usually, there is not enough loose material on the road surface to use in the road mix. In this case, it is best to blade the loose material on to the should rather than perform the several operations that are [illegible] it with [illegible] material brought in from other sources.

Sometimes, however, incorporating the existing material [illegible] roadbed into the mixture; is considered practical, if it is uniform and [illegible] is available. When this is done, the loose aggregate first must be bladed into a windrow and measured. Next, it must be made to meet grading specifications by adding other aggregates as necessary. Finally, the windrow is built up to the required volu with imported material that meets the specifications.

If two or more materials are to be combined on the road to be surfaced, each should be placed in its own windrow. These windrows are then mixed together thoroughly before asphalt is added.

CONTROL OF ASPHALT: Asphalt is added to the aggregate from an asphalt distributor or by a travel mixer. Whichever method is used, close control of quantity and viscosity is required to ensure a proper mixture. Maintaining the correct viscosity is critical because the asphaltic material must be fluid enough to move easily through the spray nozzles and to coat adequately the aggregate particles. Penetration asphalts, and occasionally emulsified asphalts, even though already fluid, require some heating in order to bring them to a viscosity suitable for spraying. If the proper grade of asphalt has been used, and the mixing is done correctly, penetration or emulsified asphalt will remain fluid until the completion of mixing.

As the actual temperature of the mixture is controlled by that of the aggregate, care must be taken to see that mixing is not attempted at aggregate temperatures below 10°C (50°F). When using penetration grade asphalt the temperature of the liquid asphalt should not fall below 350°C.

2. MIXING.

<u>Travel-Plant Mixing.</u> Travel-plant mixing offers the advantage of closer control of the mixing operation than is possible with blade mixing.

With the windrow-type travel plant, the machine moves along the windrow, picking up the aggregate, mixing it with asphalt in a pugmill, and depositing the mixture in a windrow, ready for aerating or spreading. For this type of plant, the asphalt application rate must be matched accurately with the width and thickness of the course, forward speed of the mixer, and the density of the in-place aggregate. As the thickness is specified, the density is fixed, and the asphalt application rate is set, the variable is the forward speed.

If the aggregate windrow is so large that all of the asphalt cannot be incorporated in one mixing pass, it should be split into two or more windrows and the proper amount of asphalt added to each windrow as it is mixed.

Sometimes, further mixing of the windrowed material may be necessary after the addition of the asphalt. Unless the travel mixer can be used as a multiple pass mixer, this additional mixing usually is done with a motor grader. This ensures that all of the windrowed material is incorporated into the mix. It also aerates the mixture for the removal of diluents.* The number of passes with the motor grader required for this purpose varies with different job conditions. After the mixing and aeration procedure is completed, the windrow should be moved to one side of the area to be surfaced in preparation for spreading.

Hopper Mixer. The hopper-type travel plant operates by mixing, in its pugmill, the proper amount of asphalt with aggregate that is deposited by haul trucks, roto-mills or windrow loaders, directly into the plant's hopper; then it spreads the mixture. Except when using open-graded mixtures, care must be taken to ensure sufficient evaporation of diluents from the mix prior to compaction.*

Rotary Mixing. As with windrow travel plants, rotary mixers equipped with built-in spraying systems require that the asphalt application rates be matched accurately with the width and thickness of the course, forward speed of the mixer, and the density of the in-place aggregate. However, when utilizing a rotary mixer not equipped with spraybars, an asphalt distributor, operating ahead of the mixer, applies asphalt to the aggregate. Incremental applications of asphalt and passes of the mixer are usually necessary to achieve the specified mixture.

Most rotary mixers are now equipped with a spray system. When using this type of mixer the following steps are recommended:

1. Spread the aggregate to uniform grade and cross section with motor graders.

2. Thoroughly mix the aggregate by one or more passes of the mixer. When ready for the asphalt the moisture content of the aggregate should not exceed three (3) percent, unless laboratory tests indicate that a higher moisture content will not be harmful when the asphalt is added.

3. Add asphalt in increments of about 2.25 litres/m2 (0.50 gal/sq yd) until the total required amount of asphalt is applied and mixed in. A total of 0.7 to 1.1 litre/m2 per centimetre (0.4 to 0.6 gal sq yd per inch) of compacted thickness of the course is usually necessary. If the mixer is not equipped with spraybars the asphalt usually is applied with an asphalt distributor.

4. Make one or more passes of the mixer between applications of asphalt, as necessary to thoroughly mix it in.

5. Maintain the surface true to grade and cross-section by using a motor grader during the mixing operations.

6. Aerate the mixture by additional manipulation, if needed.*

Blade Mixing. With blade mixing, the imported or in-place material is shaped into a measured windrow, either through a spreader box or by running through a windrow shaper. The windrow is then flattened with the blade to about the width of the distributor spraybar. The asphalt is applied by successive passes of the asphalt distributor over the flattened windrow, each application not exceeding 3.5 litre/m2 (0.75 gal/sq yd).

---

* Indicated by a marked color change from brown to black.

After each pass of the distributor the mixture is worked back and forth across the roadbed with the blade, sometimes aided by auxiliary mixing equipment. Prior to each succeeding application of asphalt, the mixture is re-formed into a flatte windrow.

The material in the windrow is sugjected to as many mixings, spreadings, shap and flattenings, as are needed to disperse the asphalt thoroughly throughout the mixture, and to coat effectively the aggregate particles.

During mixing, the vertical angle of the mold board may require adjustment fr time to time in order to achieve a complete rolling action of the windrow as it is worked. As large a roll as possible should be carried ahead of the blade, since pressure from the weight of the aggregate facilitates mixing.

Additionally, during mixing, care must be taken to see that neither extra material be taken from the mixing table and incorporated into the windrow nor any of the windrow be lost over the edge of the mixing table or left on the mixing tab without being treated.

Sometimes, when cutback asphalt is used, the formation of "oil balls," i.e., concentrated clusters of fine aggregate saturated and coated with excessive amounts of asphalt can make a mix difficult to spread and compact. This condition can be corrected by windrowing the mixture into a tight windrow and allowing it to cure for a few days.

After mixing and aeration have been completed, the windrow is moved to one side of the roadbed in readiness for subsequent spreading. If it is left for any length of time, periodic breaks in the windrow should be cut to ensure drainage of rainwater from the roadbed.

3. AERATION.

Before compaction, most of the diluents that have made the asphalt cold mix workable must be allowed to evaporate. In most cases, this occurs during mixing and spreading and very little additional aeration is required. But, extra manipulation on the roadbed is needed occasionally to help speed the process and dissipate the excess diluents. Until the mix is sufficiently aerated, it usually will not support rollers without excessive pushing under the rolls. Generally, the mixture is sufficiently aerated when it becomes tacky and appears to "crawl".

Many factors affect the rate and the required amount of aeration. Fine-grained and well-graded mixtures will require longer aeration than open-graded and coarse-grained mixtures, all other things being equal. Also, If an asphalt cold-mix base course is to be surfaced within a short length of time, aeration before compaction should be more complete than if the course is not to be surfaced for some time; the surface acts as a seal, greatly retarding the removal of diluents.

<u>Emulsified Asphalt Mixes.</u> Experience has shown that breakdown rolling of emulsified asphalt mixes should begin immediately before, or at the same time as, the emulsion starts to break.* About this time, the moisture content of the mixture is sufficient to act as a lubricant between the aggregate particles, but is reduced to the point where it does not fill the void spaces, thus allowing their reduction under compactive forces. Also, by this time, the mixture should be able to support the roller without undue displacement.

<u>Penetration Asphalt.</u> When using penetration grade asphalt it must be used with a multi-shaft or travel plant. It is not necessary to aerate this type of material. When mixing with penetration asphalt a better mix can be obtained by adding water or aerateing the material to be mixed until the moisture content is between 3% and 7%. If over mixed or aerated the asphalt emulsion will have a tendency to break out and the mix will become unstable.

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*Indicated by a marked color change from brown to black.

Spreading and Compacting. With mixing and aeration completed, spreading and compacting the cold mix follows. Achieving a finished section and smooth riding surface conforming to the plans is the objective of these final two construction steps.

The mixture should always be spread to a uniform thickness (whether in a single pass or in several thinner layers) so that no thin spots exist in the final mat. Mixtures that do not require aeration may be spread to the required thickness immediately after mixing, and then compacted with pneumatic-tired vibratory, or steel-tired rollers, or combination there of.

Mixtures that require aeration, however, generally are deposited upon the roadbed in windrows and then are spread from these windrows. The windrow may be placed along the centerline of the road, or along one side if the mixture is to be spread by blade. Because there is a tendency to leave a hump in the road when blade spreading from a centerline windrow, it is considered better practice to place the windrow to the side for spreading.

Blade Spreading should be accomplished in successive layers, with no layer thinner than about 1.5 times the diameter of the maximum particle size. As each layer is spread, compaction should follow almost immediately with a pneumatic-tired roller.

Because the tires of the motor grader compact the freshly spread mix, their tracks will appear as ridges in the finished mat unless there is adequate rolling between the spreading of each successive layer. The roller should follow directly behind the motor grader in order to eliminate these ridge marks.

If, at any time during compaction, the asphalt mixture exhibits undue rutting or shoving, rolling should be stopped. Compaction should not be attempted until there is a reduction in diluent content, occurring either naturally or by mechanical aeration.

After one course is thoroughly compacted and cured, other courses may be placed on it. This operation should be repeated as many times as necessary to bring the road to proper grade and crown. For a smooth riding surface the motor grader should be used to trim and level as the rollers complete compaction of the upper layer.

After the mat has been shaped to its final required cross-section, it must then be finish rolled, preferably with a steel-tired roller, until all roller marks are eliminated.

Sometimes, a completed course may have to be opened temporarily to traffic. In this event, to prevent tire pickup, it may be advisable to seal the surface by applying a dilution of slow-setting emulsified asphalt and potable water (in equal parts) at a rate of approximately 0.45 litre/m2 (0.10 gal/sq yd). This should be allowed to cure until no pickup occurs. For immediate passage of traffic, sanding may be desirable to avoid pickup.

4. INSPECTING AND SAMPLING.

The final quality control of materials and construction methods must be accomplished through on-the-job inspection. Sampling and testing must be done as required by the specifications. The responsibility rests with the field personnel to see that the materials used meet the requirements of the specification and that the specified procedures are followed.

Whatever process is used the depth control of the material being recycled is of the utmost importance. One inch more or less can change the % of asphalt by 25%. EXAMPLE: If you are planing a 4" recycled base and you crush and mix 3" or 5" and do not increase or decrease the amount of asphalt, you can readily see that you will not get the end product required. The depth control can only be controlled in the field and must be controlled continuously throughout the job.

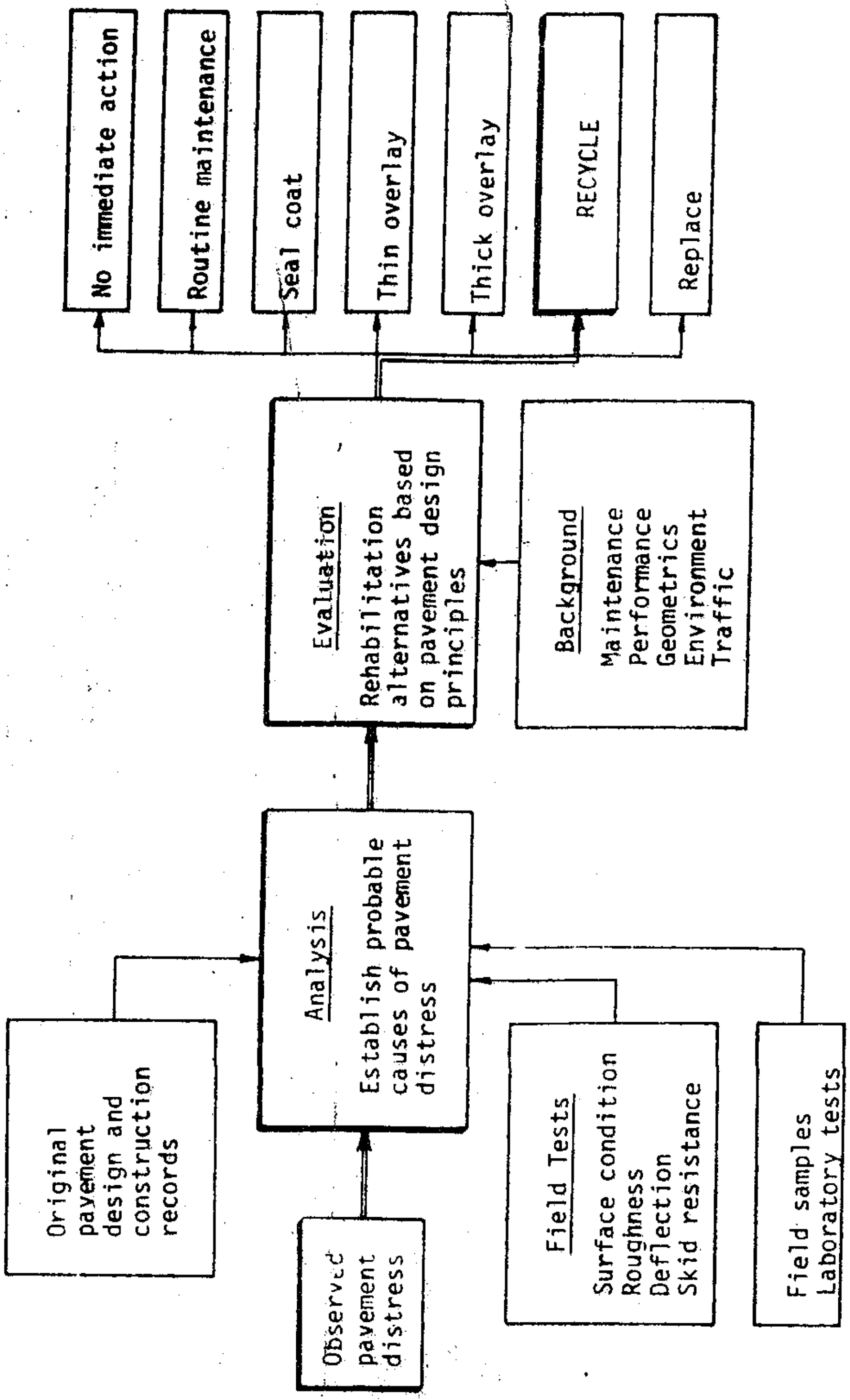

FIGURE 2. Recycling as a rehabilitation alternative.

Proposed

SUPPLEMENTAL SPECIFICATION

SHOULDER STABILZATION - BITUMINOUS
STABILIZED IN PLACE

____.01 Description. - This work shall consist of pulverizing, crushing, adding new new material as required, shaping to the plan grade for stabilizing with bituminous material, and shaping, rolling and compacting the stabilized aggregate to the proper elevation and slope.

____.02 Materials. - The bituminous materials shall meet the requirements specified in Division 8, as follows:

Bituminous Materials. 8.04

MS-2h, Asphalt Cement: Penetration Grade 120-150, 200-250;

Viscosity Grade AC-5, AC-2.5

The bituminous material shall be applied at the rate,as determined by the Engineer, so that the residual bitumen added will be between 2 and 5 percent by weight of the bituminous mixture. Residual bitumen content shall be computed based on the residue of the bituminous material being applied.

When the bituminous material to be used is not specified on the plans or in the proposal, the Contractor shall select one of the bituminous materials specified above.

Aggregate. 8.02

When aggregate is added, it shall be any 20 series aggregate with a maximum

loss by wash of 10 percent.

____.03 Equipment Requirements:

a. Rollers - Adequate rollers will be required to provide the required density while the stabilized material is in a workable state.

b. Crushing Equipment - When the existing shoulder consists of a bituminous mat or a bituminous mat with Seal Coat, crushing equipment will be required. The equipment shall be of rotary reduction, or hammer-mill type, or equipment approved by the Engineer that is capable of reducing the existing pavement material to the specified size.

c. Mixers - Mixers shall be a combination pulverizer, mixer, and liquid distributor and be self-propelled. The mixer shall be a single-pass stabilizer, combining a cutting rotor, a blending rotor, and at least one mixing rotor in the mixing chamber. The spray bar for distribution of the liquid shall operate in such a manner that all asphalt will be uniformly applied through the mixer at the time of mixing.

The equipment for distributing the bituminous material shall be adjustable and shall measure accurately the amounts of bituminous material being applied. The bitumen pump shall be a positive displacement type pump. It shall be equipped in such a manner as to make it possible to check accurately the rate of application of the bitumen at any time. The mixer shall meet the approval of the Engineer.

CONSTRUCTION METHODS

____.04 Pulverizing. - The material shall be uniformly pulverized to a maximum size of 2 inches, except that 5 percent of the material may be oversized, provided that the oversized material is not so large as to adversely affect the stability and structural integrity of the mixture nor hamper the shaping operations. The material shall be uniformly pulverized, in one or more passes, to the depth specified on the plans or in the proposal.

____.05 Preliminary Shaping. - Preliminary shaping will be required when the existing shoulder has to be pulverized or in areas where it is necessary to add aggregate. When preliminary shaping is required, it will be done after the existing shoulder has been pulverized and additional aggregate has been added to obtain the established cross-section. The shoulder shall then be rough graded to the established graded and cross-section within a tolerance of ±3/4 inch. If maintenance ridges are present, the ridges shall be bladed in such a manner to incorporate it in the material to be stabilized. When additional aggregate is needed, it shall be placed as directed by the Engineer, and be placed on the shoulder with an approved shoulder spreader or other approved methods.

____.06 Mixing. - Prior to adding the bituminous material, the moisture content of the pulverized material shall be adjusted by aerating or adding water as directed by the Engineer. The bituminous material shall be added only to that material which can be aerated, dried, completely mixed, and compacted in one day. The bituminous material shall be added through the mixer at the rate and within the temperature range directed by the Engineer. Areas where the single pass stabilizer cannot be operated efficiently, (such as guard rail sections, bridge approaches, and ramps) will be trenched and bituminous aggregate shoulders will be placed.

____.07 Shaping, Rolling, and Compacting. - Shaping and compaction shall be done while the bituminous material is in a workable state. The mixed material shall be so shaped that when compacted it shall be in reasonably close conformity with the lines, grades, and cross-sections shown on the plans or established by the Engineer. Excess material trimmed from the grade, during final shaping, shall be used adjacent to the shoulder to complete the cross-section as shown on the plans. This material used to complete the cross-section shall be incidental to the item of Bituminous Base Stabilization and will not be paid for separately or as another item of work, as long as it is not necessary to pick up the material and move it to complete the cross-section. If there is material in excess of the quantity required to complete the cross-section, and the material cannot be disposed of on the adjacent slopes as directed by the Engineer, it will be disposed of outside the right-of-way. If this material is picked up, it will be paid for under item of Removal of Excess Material.

Initial rolling shall be done with a Pneumatic-tired roller or rollers, and the final rolling shall be done with a vibratory roller or rollers. The aggregate-bituminous mixture shall be compacted to not less than 98 percent of the unit weight obtained by the Department modified AASHTO T 180 test method. Such test shall be made on the aggregate-bituminous mixture at the field moisture content existing during the compacting operation. Required density shall be maintained until the material has been surfaced. When using asphalt cement, the distance between the adding of bituminous material in the stabilizer and final compaction shall be kept to a minimum, so that compaction is completed while the material is in a workable state.

After final rolling, the Engineer will test the surface longitudinally using a 10' (ten foot) straightedge at selected locations. The variation of the surface from the testing edge of the straightedge between any two contacts with the surface shall at no point exceed ±3/4 inch.

____.08 Curing. - If the stabilized base is scheduled to be open to traffic prior to placing the surface course, it shall be cured a minimum of 24 hours before opening to traffic.

____. 09 Weather Limitations. - Bituminous material shall not be applied to the aggregate when it is raining or the air temperature is lower than 50 degrees F.

The stabilization work shall be performed in the Lower Peninsula during the period May 15 to October 15 and in the Upper Peninsula during the period June 1 and October 1 unless directed otherwise by the Engineer.

____. 10 Measurement and Payment. - The completed work as measured for Shoulder Stabilization - Bituminous Stabilized in Place will be paid for at the contract unit prices for the following contract items (pay items).

Pay Item	Pay Unit
Shoulder Stabilization - Bituminous	Square Yard
Bituminous Material - Shoulder Stabilization	Gallon
Aggregate - Shoulder Stabilization	Ton
Aggregate - Shoulder Stabilization (LM)	Cubic Yard
Removal of Excess Material (LM)	Cubic Yard

Shoulder Stabilization - Bituminous, to the depth specified, will be measured in square yard.

Bituminous Material - Shoulder Stabilization required for stabilization will be measured by volume in gallons of residual bitumen at a temperature of 60 degrees F in accordance with the methods specified under Measurement of Quantities, 1.09.01.

Aggregate - Shoulder Stabilization - Ton. When additional aggregate is required, the additional aggregate will be measured by weight in tons as Aggregate - Shoulder Stabilization. The pay weight for the aggregate used will be based on the scale weight of the material, provided the moisture content, determined at the time of weighing, does not exceed 6 percent. If the material contains more than 6 percent moisture, the excess over 6 percent will be deducted from the scale weight. No correction or additions will be made to the scale weight if the aggregate contains less than 6 percent moisture. The determination of moisture content and pay weights will be as specified under Measurement of Quantities, 1.09.01.

Aggregate - Shoulder Stabilization (LM) - Cubic Yard. When additional aggregate is required, the additional aggregate will be measured in cubic yards, loose measure, as Aggregate - Shoulder Stabilization (LM). The method of measurement shall be 80 percent of the struck capacity of the truck box of the transporting unit.

Removal of Excess Material (LM) - Cubic Yard. When removal of excess material is required to be picked up, loaded, and transported in a truck, this material will be measured in cubic yards, loose measure, as Removal of Excess Material (LM). This material is the property of the Contractor unless otherwise specified. The method of measurement shall be 80 percent of the struck capacity of the truck box of the transporting unit.

RECYCLED ASPHALT THROUGH A BATCH PLANT

by Bill McCullough

Our company, Sully-Miller Contracting Company, was successful in acquiring the first publicly bid job in Southern California containing recycled asphalt materials. This job had an end result specification which called for a type 1-C 1/2" max. hot mixed asphalt pavement per the Green book. The specifications read,"The contractor was to meet all requirements equal to or better than the standard type 1-C mix." (See pg 12 Appendix for specified gradation).

The job was located in the City of Carson. The Field Materials Laboratory Engineer for the City was Fred Thompson. The Los Angeles County Road Department Materials Laboratory, under the supervision of Joe Vicelja, coordinated the quality control portion of the project. The recycled asphalt concrete for this project was mixed in a batch plant using the Maplewood process (Maplewood, Minnesota -1976). Our procedure was to take cores for extractions. We evaluated the viscosity and gradation of the existing pavement from which we were able to prepare a mix design incorporating new aggregates to meet the specified gradation. Tests of the recovered asphalt were made to determine if a soft paving asphalt or a recycling agent would be required to meet the viscosity requirements. The existing streets were excavated and transported to a remote location where the asphalt concrete was crushed and sized, then transported to a stockpile at the hot mix asphalt plant site. Superheated virgin aggregates were used for heat transfer in the pugmill.

HISTORY

Sully-Miller Contracting Company, primarily a highway contractor in Los Angeles and Orange counties, had a series of problems with jobs in the early sixties. The situation developed where disposal locations, which had been anticipated for the disposal of rubble from street excavation, were unavailable by the time project was to be constructed, this resulting in additional haul costs for these projects. We experimented with the idea of crushing rubble as it was excavated from the street. We found this to be impractical because of changes in grades, utilities, noise, and timing.

To overcome these problems, we developed a system of disposal locations where the rubble could be transported; and, as the pile of material reached an adequate size, we would bring in a large portable crusher to reduce the rubble to what was then called crushed miscellaneous base materials.

In our experiments of processes for reducing this material, we had worked with hammermills, roll crushers, and ultimately decided upon a jaw and cone combination.

EARLY EXPERIMENTATIONS

In the early sixties, we experimented with processing concrete rubble seperate from asphalt pavement as a potential aggregate source for our hot mix asphalt pavement business. The processing, and necessary control, made this system void of any economic advantages. We also experimented with introducing a small percentage of crushed asphalt pavement into the raw feed of our asphalt plant. The result was an extremely visible emission of smoke from the stacks of the plant. At this time, the country's interest was shifting to enviromental concerns and the fact that, in the early seventies, a ton of paving asphalt was $21.00, we felt that the problem of overcoming the emission problems were not economically advisable. In 1976, in Maplewood, Minnesota, a project was sucessful in introducing the recycled material into the weigh hopper of a hot mix asphalt batch plant to receive a heat transfer from a preheated virgin aggregate as they were combined in a new mix.

The drum mix plant entered the market about this time, and experimentations had developed where it became feasible to introduce the recycled old pavement into the drum for heating and mixing. Through all of this period, we were never able to receive any confirmed reports from the manufacturers that the HO or hydrocarbons were not an emission problem for the plant. It seemed logical to us that they had to be. They were visibly evident in plants which we had visited; and, therefore, we did not believe this process would be compatible with the Los Angeles area.

With the increase cost of paving asphalt and aggregate in the late 70's, we reevaluated the economics of converting a plant to handle recycled asphalt concrete. By use of the Maplewood process, it is economical to produce hot mix asphalt concrete incorporating 20 to 30 percent recycled asphalt pavement (RAP) and meet the local air pollution standards.

EXCAVATION

The two primary methods for pavement excavation are milling or total excavation using trucks and loaders. This project called for the total removal of the existing streets in a residentail area. The streets were approximately 40 years old and showed extreme allegatoring and age cracking of the pavement. Because of the condition of the pavement and our crushing capabilities, we elected to remove the pavement with loaders. The streets involved were Harbor View, Van Buren, Tyler, and Prospect. These streets are located north of the San Diego Freeway and east of Alameda Street and required a combined tonage of approximately 4,000 tons of recycled asphalt concrete.

The testing design for the type 1-C recycled mix was accomplished by in-house, Los Angeles County Road Department, and Edington Oil Company Laboratories. The services of a private independent laboratory were also used. Extraction tests, gradation analyses, asphalt viscosity and blends were evaluated. The appendix shows some of these test results, and our company's mix design for using 20%, 30% and 40% of recycled materials. The analysis, you will note, indicates an oil which is harder than the specified AR-4000. We had the choice of using an AR-2000, or an RA-500 oil which contained a recycling and rejuvenating agent, which was combined then with the existing oil in the RAP to meet the requirements of an AR-4000. We elected to use the AR-2000 oil because of the economic advantages of this standard oil over the recycling agents. The intent was to use 20% recycled and try some 30%. The mixing went so well that some 40% was also tried. We were able to meet the gradation and predicted the increased viscosities, shown on page 22 of the Appendix, for the recycled mixture.

CRUSHING

The specifications required 1/2" max size, and extraction tests indicated the existing pavement would meet this requirement. In the slides I am about to show, you will note our crushing operation includes a scalping operation to eliminate the existence of an undesirable material which was adhearing to the bottom of the pavement as it was excavated. This scalping operation eliminated all material, minus 1", after it had gone through the jaw crusher. The remaining asphalt was reduced with a cone crusher and screened through a 1 1/8" product screen size.

We were trying to be selective in our excavation of the street, and still we found the approximately 1/2 of the material processed was lost in the scalping operation.

To minimize the potential problems resulting from stockpile segregation, we loaded the crushed, minus 1 1/8", asphalt directly into trucks for transportation and storage at our Hot Mix asphalt batch plant. To minimize the amount of moisture, this material was covered.

MIXING

The Maplewood mixing process was accomplished at our Torrance plant location. The plant was approximately 20-30 minutes from the job site in the city of Carson.

The plant is 12,000 lb. Standard Steal batch plant which is modified to allow us to feed this crushed asphalt cold, into the weigh hopper, where it was combined with preheated virgin aggregate for heat transfer to the product in the mixer.

The modifications were the addition of a small hopper and feeder which could be fed with a loader. This hopper had to be so designed to prevent the material from bridging. The following equipment was added: A 120' x 24" conveyor to elevate the crushed asphalt to the plant, a separate feed Hopper and gate to meter the material into the Plant. We installed a special air blaster and control equipment to assure the continuous flow of this seperate feed system to assure a uniform product. All this additional equipment was then incorporated with the batching control equipment with the necessary electrical interlocks.

In the actual batching, we experimented with 20%, 30% and 40% recycled material to be added. We tried varying the dry mixing cycle. The product was maintained at 300 tons per hour, and the temperature at the lay down operation was consistently between 290° and 310°.

CONCLUSION

Recycling can be economically and mechanically sucessful under certain conditions. The job must be of adequate size to allow the necessary design and testing work. Adequate effort must be expanded to assure uniform product control.

The negative considerations are increased costs of a loader and man to feed the recycled asphalt, plant modifications, and design cost. If we continue to see escalation of paving grade asphalt oil costs, these negative factors will be overcome by the savings in oil costs.

BLUE DIAMOND MATERIALS
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APPENDIX

HOT RECYCLED ASPHALT

(BATCH PLANT)

by WILLIAM D. McCULLOUGH

BLUE DIAMOND MATERIALS
3000 EAST SOUTH STREET / P.O. BOX 5399 / LONG BEACH, CALIFORNIA 90805 / (213) 979-1873

CITY OF CARSON - PROJECT 370 - RECYCLED PAVEMENT

INFORMATION SHEET

I. Extraction tests of cores removed from Van Buren and Harbor View Streets by La Belle Consultants

II. Edgington Oil's report on the blending of the recovered asphalt with virgin asphalt

III. Calculation of virgin asphalt and aggregate required - A) at 20%, B) at 30%

IV. Bin pulls, specifications and combined gradations

V. Formula for calculating temperature of virgin aggregate necessary to achieve desired temperature of recycled mix

VI. Temperature calculations

VII. Plant production

VIII. Product results

LA BELLE
CONSULTANTS

Pavement Analysis
Deflection Testing
Soil Stabilization
Asphalt Technology

2700 S. Grand Ave. • Santa Ana, Calif. 92705 • (714) 546-3468

March 4, 1981

Mr. Ed Alheim
BLUE DIAMOND MATERIALS
3000 E. South Street
Long Beach, CA 90805

Asphalt Concrete Recycling
Project No. 12247

Dear Mr. Alheim:

Laboratory testing of the asphalt concrete core samples received February 13, 1981 has been completed, and their suitability for a recycling project has been evaluated. The results of laboratory testing are tabulated and attached.

Two cores, labeled Van Buren and Harbor View, No. 13 & 14, were selected for testing. They were mixed together, extracted, the asphalt cement was recovered by Abson Method, and the extracted aggregate was evaluated for gradation. The Penetration and absolute viscosity were determined for the recovered asphalt. The asphalt demand was determined for the extracted aggregate through a numerical method developed by the Golden Bear Division of Witco Chemical Corporation. Comparison of the asphalt demand to the asphalt content determined by extraction has revealed that asphalt is donated to the mix in the amount of 0.3 to 0.4 per cent of weight of dry recycled aggregate. The proposed proportioning of 80% virgin material to 20% recycle material was adjusted to account for the asphalt donated by the recycle material. While the proportioning of the aggregate must remain at 20%/80%, the asphalt cement proportions are altered to 21% reclaimed asphalt, 79% virgin asphalt. A 5.5% asphalt content for the new combined mix was assumed.

From the results of laboratory testing one may conclude that the reclaimed aggregate has an asphalt content such that 0.3 to 0.4 per cent of the dry weight of recycled aggregate is contributed to help coat the virgin portion of the new mix. The viscosity and penetration characteristics of the asphalts combined in the proposed proportions are within the specification for an AR 8000 paving grade asphalt.

The virgin asphalt provided by Blue Diamond for use in the investigation is an AR 4000. Should the job specification call for the viscosity of the virgin asphalt mixed with the recovered asphalt to meet the specification for AR 4000, virgin asphalt should be changed to an AR 2000 or a softening agent must be added, to be confirmed by laboratory testing.

Factors off-setting the savings associated with recycling are many, and should be carefully evaluated. The savings are only those that can be attributed to substituting relaimed asphalt and aggregate for virgin asphalt and aggregate. Obvious costs are hauling and crushing costs. For this project using these materials, and asphalt softening agent does not appear to be required.

The reclaimed material must be heated in the pug mill through a heat transfer process. That is to say, the reclaimed material is introduced to the pug mill cold, and is raised to mixing temperature through contact with super-heated virgin aggregate. The resulting temperature must be such that the materials can be thoroughly mixed. typically in the range of 310F to 325F. This requires that the virgin aggregate be introduced to the pug mill at a temperature in the range of 400F to 550F, dependent upon time of delay in the hot bins and the weather conditions. The additional costs for super-heating the aggregate are often a prohibitive factor in evaluating a recycle project.

The opportunity to be of service is sincerely appreciated, and should you have any questions in this matter, kindly call.

Yours very truly,

Stephen M. Milazzo
Project Engineer
EIT 43989

Reviewed by:

Steven R. Marvin
Vice President
RCE 30659

SMM/dmm

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CONVENTIONAL MIX

MATERIAL	% USED BY AGGREGATE WT.	% USED BY TOTAL MIX	BATCH WEIGHT **
Virgin Aggregate	100	94.8	11,375 lbs.
New Asphalt Cement	5.5	5.2	625 lbs.
Total Asphalt Cement	5.5	5.2	

** 12,000 Pound Batch

PROPOSED RECYCLE MIX

MATERIAL	% USED BY AGGREGATE WT.	% USED BY TOTAL MIX	BATCH WEIGHT **
Virgin Aggregate	80.0	75.8	9,100 lbs.
Reclaimed Material	21.2	20.1	2,407 lbs.
New Asphalt Cement	4.3	4.1	493 lbs.
Total Asphalt Cement	5.5	5.2	

** 12,000 Pound Batch

ASPHALT CONCRETE TESTING

(Core Samples No. 13 & 14 Combined, Van Buren & Harbor View)

MECHANICAL ANALYSIS

Gradation, % Passing

Sieve No.	Extraction #1	Extraction #2
3/4"	100	100
1/2"	97	99
3/8"	95	97
No. 4	61	61
No. 8	37	40
No. 16	26	28
No. 30	19	20
No. 50	14	14
No. 100	8	9
No. 200	5	5
Asphalt Content (Agg. Wt. = 100%)	5.9%	5.7%
Asphalt Demand of Extracted Aggregate	5.4%	5.4%
Excess Asphalt Cement	0.4%	0.3%

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A S P H A L T   C E M E N T   T E S T I N G

TESTS ON ORIGINAL ASPHALT (labeled AR 4000)	RESULTS
Absolute Viscosity @ 140F (virgin asphalt)	2027 poise

TESTS ON RECOVERED ASPHALT	
Absolute Viscosity @ 140F	22,107 poise
Penetration @ 77F	17

Theoretical Mixing Viscosity of Asphalts Combined in Proportions of 21% Recovered Asphalt, 79% Virgin Asphalt is 3400 poise.

TESTS ON COMBINED ASPHALT CEMENTS

Proportion: 21% Recovered Asphalt, 79% Virgin Asphalt

TESTS ON RTFC RESIDUE	RESULT	AR 8000 SPECIFICATION
Absolute Viscosity @ 140F	7099 poise	6,000-10,000
Penetration @ 77F	26	20 minimum

INTER-OFFICE CORRESPONDENCE

DATE MARCH 23, 1981

TO J. ALLEN

FROM W. E. HAM WEH

SUBJECT ASPHALT CONCRETE CORE SAMPLES
BLUE DIAMOND MATERIALS - RECYCLE AGENTS

Attached are Laboratory Reports covering work the Laboratory performed on asphalt concrete cores that Ed Ahlheim of Blue Diamond Materials submitted to the laboratory.

Blue Diamond Materials and L. A. County Road Department are engaged in a pavement recycle project in the City of Carson. Mr. Ahlheim requested that we provide data showing the effect of adding soft paving asphalts and/or recycle agent back to a mixture of virgin aggregate and crushed recycled pavement. The object of the experiments was to soften the asphalt in the crushed recycle pavement to the AR-4000 grade and provide AR-4000 grade asphalt to cover the virgin aggregates. The subject materials are to be heated, mixed in a pug mill, then spread and compacted on a roadway.

Our data shows that Edgington's AR-2000 and recycle agent RA-500 would be suitable recycle agents to use on the subject project. Our test data are attached.

We understand that you will be transmitting these Laboratory Reports to Mr. Ahlheim in the very near future. We would appreciate the opportunity to observe a plant run and lay-down operation using these materials.

WEH:las

cc: M. L. Smith
R. O. Friend

(213) 423-1465 CABLE ADDRESS EDOOIL (213) 636-2524

Edgington Oil Company, Inc.
2400 EAST ARTESIA BOULEVARD
LONG BEACH CALIFORNIA

LABORATORY REPORT

Sample Asphalt Pavement Cores — Date March 6 1981

Source Blue Diamond Materials — Sample Date Unknown 19
SSR#501-301-S

Test		Dominguez and Harbor View	Tyler and Van Buren	Tyler and Prospect
Extraction				
Recovered Asphalt, wt.%		7.4	6.1	6.5
Recovered Aggregate, wt.%		92.6	93.9	93.5
Tests on Recovered Asphalt				
Viscosity @ 140°F, poise		121,371	68,354	72,489
Tests on Recovered Aggregates		Weight % Passing		
Sieve Size:	1/2"	100	100	100
	3/8"	99	99	98
	No. 4	69	60	61
	No. 8*	46	38	37
	No. 30*	22	21	19
	No. 100*	8	14	7
	No. 200*	5.4	5.3	4.5

* Water washed

213) 423-1465 CABLE ADDRESS EDGOIL (213) 636-2524

Edgington Oil Company, Inc.
2400 EAST ARTESIA BOULEVARD
LONG BEACH CALIFORNIA
90805

LABORATORY REPORT

Sample Asphalt Recovered from Domenquez & Harbor View Core

Date March 13 19 81

Source Blue Diamonds Material

Sample Date ________ 19 ____

SSR #501-301-S

TEST	RESULTS Wt% Used #1	#2
Blends		
Recovered Asphalt	20	20
Paving Asphalt AR-2000	80	[illegible]
Recycle Agent RA-500	—	80
Tests on Blends		
Viscosity @ 140°F, poise	1981	1251
Viscosity @ 275°F, eST	294	251
Penetration @ 77°F, 100G, 5 SEC	62	100
RTFC, 85 min. @ 325°F, wt% loss	0.5	0.6
Tests on RTFC Residue		
Viscosity @ 140°F, poise	4423	2692
Viscosity @ 275°F, eST	414	351
Penetration @ 77°F, 100G, 5 SEC	41	60

BLUE DIAMOND MATERIALS
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A. Calculation of virgin asphalt and aggregate required at 20% recycle:

Batch Size

Total Batch	12,000 LBS
80% Virgin	9,600 LBS
20% Recycle	2,400 LBS

Asphalt content of recycled materials based on extraction tests is 5.7% of the dry aggregate. Type 1C only requires 5.3% of the dry aggregate; therefore, amount of asphalt donated by the recycle equals:

(2,400 LBS ÷ 1.057) - 2,400 LBS = 130 LBS
(2,400 LBS ÷ 1.053) - 2,400 LBS = 121 LBS
Donated 9 LBS per batch

Amount of asphalt normally required by virgin aggregate = 5.3% of dry aggregate. With the 9 LBS donated by the recycle, the amount of virgin asphalt per batch equals:

(9,600 LBS ÷ 1.053) - 9,600 LBS = 483 LBS - 9 LBS = 474 LBS

Therefore at a 20% recycle rate, the batch will consist of the following ingredients:

474 LBS of virgin asphalt
130 LBS of asphalt from recycle
2,270 LBS of aggregate from recycle
9,126 LBS of virgin aggregate
12,000 LBS

B. Calculation of virgin asphalt and aggregates required at 30% recycle:

Batch Size

Total Batch	12,000 LBS
70% Virgin	8,400 LBS
30% Recycle	3,600 LBS

(3,600 LBS ÷ 1.057) - 3,600 LBS = 195 LBS
(3,600 LBS ÷ 1.053) - 3,600 LBS = 182 LBS
Donated to Mix 13 LBS

(8,400 LBS ÷ 1.053) - 8,400 LBS = 423 LBS - 13 LBS = 410 LBS

Therefore at 30% recycle, the batch will consist of the following ingredients:

410 LBS of virgin asphalt
195 LBS of asphalt from recycle
3,405 LBS of aggregate from recycle
7,990 LBS of virgin aggregate
12,000 LBS

PLANT SCREEN ANALYSIS

CONTRACTOR SULLY-MILLER
JOB LOCATION CITY OF CARSON
MATERIAL TYPE 1C RECYCLE

DATE MARCH 20, 1981
SAMPLED BY
PLANT TORRANCE

									REMARKS
PERCENT	19%	14%	28%	18%	1%	20%			
WEIGHT									20% Recycle
PASSING.	4 Bin	3 Bin	2 Bin	1 Bin	Dust	Rcy	SPECS	COMB	ACTUAL BIN PULL WEIGHTS
1"	100								4 - 2,167 LBS
3/4"	100	100				100	100	100	3 - 1,597 LBS
1/2"	94	100				97	90-100	98.2	2 - 3,195 LBS
3/8"	26	85	100			95	72-88	82.8	1 - 2,053 LBS
4	1	1	45	100		61	40-54	44.0	DUST - 114 LBS
8			1	95		37	18-34	25.7	RECYCLE - 2,400 LBS
30				52		19	8-20	14.1	ASPHALT - 474 LBS
50				24		14	4-14	8.1	
200				6/9		5	1-6	3.6	

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PLANT SCREEN ANALYSIS

CONTRACTOR SULLY-MILLER

JOB LOCATION CITY OF CARSON

MATERIAL TYPE 1C RECYCLE

DATE MARCH 20, 1981

SAMPLED BY

PLANT TORRANCE

PERCENT	17%	12%	24%	16%	1%	30%			REMARKS
WEIGHT									30% RECYCLE
PASSING.	4 Bin	3 Bin	2 Bin	1 Bin	Dust	Rcy	SPECS	COMB	ACTUAL BIN PULL WEIGHTS
1"	100								4 - 1,940 LBS
3/4"	100	100				100	100	100	3 - 1,370 LBS
1/2"	94	100				97	90-100	98.0	2 - 2,741 LBS
3/8"	26	85	100			95	72-88	84.1	1 - 1,825 LBS
4	1	1	45	100		61	40-54	46.3	DUST - 114 LBS
8			1	95		37	18-34	27.5	RECYCLE - 3,600 LBS
30				52		19	8-20	15.0	ASPHALT - 410 LBS
50				24		14	4-14	9.0	
200				6/9		5	1-6	3.9	

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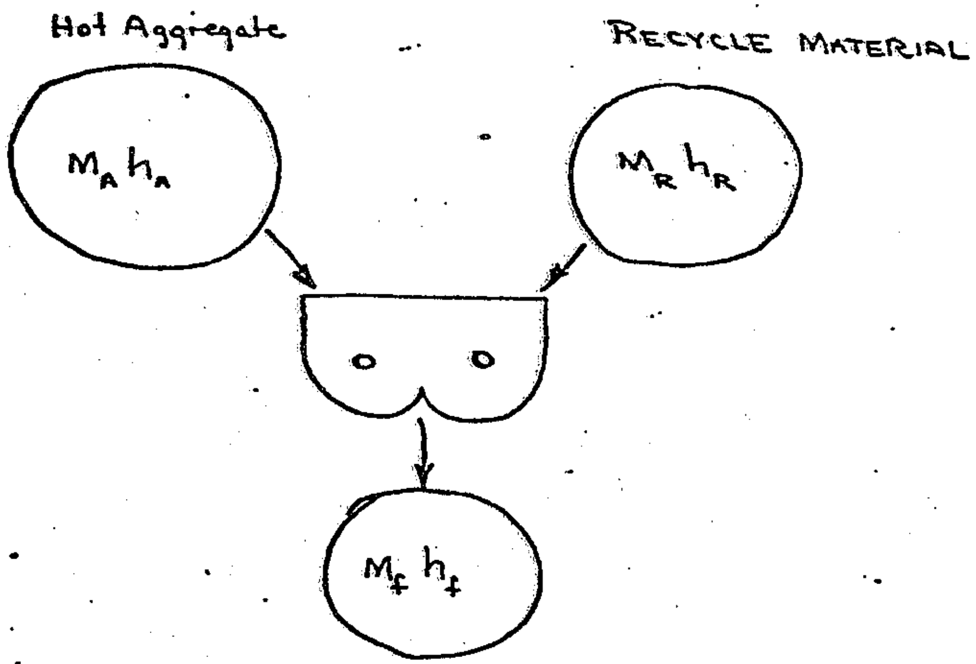

Energy Balance

$$M_R h_R + M_A h_A = M_f h_f$$

$$\frac{M_R}{M_f} h_R + \frac{M_A}{M_f} h_A = h_f$$

$$X_R = \frac{M_R}{M_f} \quad ; \quad X_A = \frac{M_A}{M_f}$$

$$X_R(-Mh_{fg} + C_{P_R} T_R) + X_A C_{P_A} T_A = C_{P_f} T_f$$

$$C_{P_R} \simeq C_{P_A} \simeq C_{P_f}$$

$$\therefore X_R\left(T_R - \frac{M}{C_P} h_{fg}\right) + X_A T_A = T_f$$

$$\boxed{T_A = \frac{T_f - X_R\left(T_R - \frac{M}{C_P} h_{fg}\right)}{X_A}}$$

T_A = Temp of Aggregate °R (°F + 460°)

T_R = Initial Temp. of Recycle Material °R (°F + 460°)

T_f = Mix Temp. °R (°F + 460°)

X_A = Ratio of Virgin Aggregate in final mix

X_R = Ratio of Recycled Material in final mix

h_{fg} = heat of Vaporization of water @ operation temperature ~ 1100 $\frac{BTU}{lb}$

M = Moisture in recycle material

$C_p = 0.2 \frac{BTU}{lb\,°F}$

BLUE DIAMOND MATERIALS
3000 EAST SOUTH STREET / P.O. BOX 5399 / LONG BEACH, CALIFORNIA 90805 / (213) 979-1873

Example 1

50% Recycle — X_R
50% Virgin — X_A
Moisture = 0 — M
$T_f = 280°F$

$$T_A = \frac{T_f - X_R\left(T_R - \frac{M}{C_p} h_{fg}\right)}{X_A}$$

$$T_A' = \frac{740 - 0.5(530 - 0)}{0.5} = 950°R = 490°F$$

Example 2

50% Recycle
50% Virgin
M = 2%
$T_f = 280°F$

$$T_A = \frac{740 - 0.5\left[530 - \frac{0.02}{0.2}(1100)\right]}{0.5} = 1060°R = 600°F$$

Example 3

10% Recycle
90% Virgin
M = 2%
$T_f = 280°F$

$$T_A = \frac{740 - 0.1\left[530 - \frac{0.02}{0.2}(1100)\right]}{0.9} = 775°R = 315°F$$

BLUE DIAMOND MATERIALS
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VI. Virgin aggregate temperature calculations

20% Recycle
2% Moisture in recycle
300° Desired temperature of recycle mix
70° Virgin aggregates initially

Virgin aggregates must be heated to:

$$\frac{760 - .2\left(530 - \frac{.02}{.2}[1100]\right)}{.8} = 845 = 385°$$

30% Recycle
2% Moisture in recycle.
300° Desired temperature of recycle mix
70° Virgin aggregates initially

Virgin aggregates must be heated to:

$$\frac{760 - .3\left(530 - \frac{.02}{.2}[1100]\right)}{.7} = 905 = 445°$$

NOTE: Actual heat transfer requires five to eight minutes and will normally take place in the truck bed. However, it is essential that the recycle and virgin are thoroughly blended. To accomplish this, we are mixing dry for 30 seconds and wet for 30 seconds.

TORRANCE PLANT

7:AM 4/13/81

TYPE 1C AR 4000 RECYCLE 20%

BIN		
4	19 %	- 2167
RECYCLE	20 %	- 2400 -4567
3	14 %	- 1597 -6164
2	28 %	- 3195 -9359
1	18 %	- 2053 -11412
DUST	1 %	- 114 - 11526
AR 2000	3.95 %	-474 -12000

DRY MIX 30 SECONDS WET MIX 30 SEC

AGGREGATE TEMP 385° MIX DISCHARGE TEMP. 300°

BAG HOUSE TEMP. 300°

RECYCLE MOISTURE 1 %

1:30 PM CHANGED DRY MIX TO 20 SECONDS

WET MIX 30 SECONDS NO PROBLEMS

TONNAGE 1,585.19

PLANT RUNNING TIME 5 HRS. 15 MIN.

PLANT AVERAGE -- 301.9 T.P.H.

TORRANCE PLANT

7 AM 4/14/81

TYPE 1C AR 4000 RECYCLE 30 %

BIN

4	17 %	- 1940	
RECYCLE	30 %	- 3600	- 5540
3	12 %	- 1370	- 6910
2	24 %	- 2741	- 9651
1	16 %	- 1825	- 11476
DUST	1 %	- 114	- 11590
AR 2000	3.42 %	- 410	- 12000

DRY MIX 20 SEC. WET MIX 30 SEC.

AGGREGATE TEMP. 445° MIX DISCHARGE TEMP. 300°

BAG HOUSE TEMP. 300°

TONNAGE 281.54

PLANT RUNNING TIME 1 HR.

PLANT AVERAGE 281.54 T.P.H.

000018

TORRANCE PLANT

8:15 AM 4/14/81

TYPE 1C AR 4000 RECYCLE 30 %

BIN			
4	17 %	- 1940	
RECYCLE	30 %	- 3600	- 5540
3	12 %	- 1400	- 6940
2	24 %	- 2741	- 9681
1	16 %	- 1825	- 11506
DUST	1 %	- 114	- 11620
AR 2000	3.17 %	380	- 12000

REDUCED ASPHALT CONTENTS 30#, ADDED

30 # TO 3 BIN

DRY MIX 15 SEC. WET MIX 30 SEC.

AGGREGATE TEMP. 445° MIX DISCHARGE TEMP. 300°

BAG HOUSE TEMP. 300°

TONNAGE 990.39

PLANT RUNNING TIME 3 HRS. 15 MIN.

PLANT AVERAGE 304.7 T.P.H.

00001

TORRANCE PLANT

12:00 P.M. 4/14/81

TYPE 1C AR 4000 RECYCLE 40 %

BIN			
4	27 %	- 3110	
RECYCLE	40 %	- 4840	- 7950
3	15 %	- 1700	- 9650
2	9 %	- 1010	- 10660
1	8 %	- 910	- 11570
DUST	1 %	- 110	- 11680
AR 2000	2.67 %	- 320	- 12000

DRY MIX 20 SEC. WET MIX 30 SEC.

AGGREGATE TEMP. 500° MIX DISCHARGE TEMP. 295°

BAG HOUSE TEMP. 325°

TONNAGE 100.83

TORRANCE PLANT

4/14/81

DATE	TONNAGE		RECYCLE USED
4/13/81	1,585.19	20 %	317.00
4/14/81	281.54	30 %	84.46
4/14/81	990.39	30 %	297.12
4/14/81	100.83	40 %	40.33
4/15/81	54.97	30 %	16.45
TOTAL	3,012.92		755.36

BALANCE OF RECYCLE

APPROX. 250.00

(213) 423-1465 CABLE ADDRESS EDGOIL (213) 636-2524

Edgington Oil Company, Inc.
2400 East Artesia Boulevard
Long Beach California
90805

LABORATORY REPORT

Sample Recycled Asphalt Pavement Date April 27 1981

Source Blue Diamond Materials Sample Date April 13, 14 1981

TEST RESULTS

City of Carson Project 370, Recycle Pavement
Blue Diamond Materials

Sample Date	4/13/81	4/14/81	4/14/81
Percent Recycled	20	30	40
Percent Virgin Material	80	70	60
Extraction			
Wt. % Asphalt	4.9	5.0	5.4
Wt. % Aggregate	95.1	95.0	94.6
Tests on Recovered Materials			
Asphalt			
Pen @ 77°F, 100G, 5 SEC	37	35	29
Viscosity @ 140°F, poise	4125	6074	8211
Aggregate			
Sieve Analysis			
Sieve Size			
1"	100	--	--
3/4"	99	100	100
1/2"	98	96	98
3/8"	83	79	80
No. 4	38	43	40
No. 8*	28	30	25
No. 30*	16	19	16
No. 100*	7	8	7
No. 200*	4.2	5.5	5.1

*Water washed

WEH:las

PRODUCING RECYCLED ASPHALT CONCRETE MIXTURES IN BATCH AND DRUM MIX PLANTS

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July 1, 1981

PRODUCING RECYCLED ASPHALT CONCRETE MIXTURES IN BATCH AND DRUM MIX PLANTS

INTRODUCTION

With the ever increasing cost of asphalt cement, aggregate, and fuel, the economics involved in the construction and resurfacing of asphalt concrete pavement structures has changed significantly in recent years. The recycling, or reuse, of the materials in the existing roadway has become popular and economically feasible. Several Canadian provinces and at least 42 of the states in the U.S. have constructed at least one hot mix recycled asphalt project. Indeed, six states have written permissive recycling specifications -- allowing the contractor the option of using reclaimed material in various asphalt concrete mixtures.

Extensive experience has been gained in the last few years with asphalt concrete pavement recycling. These projects have shown that the recycled hot mix:

* Is comparable in quality and strength to conventional hot mix asphalt concrete materials made with all new aggregates and asphalt cement,

* Will reduce the amount of new aggregate needed,

* Will reduce the amount of new asphalt cement needed,

* Can be readily produced in modified batch and drum mix plants,

* Can be produced in the asphalt mix plant in compliance with all existing air pollution control regulations, and

* Is more economical than conventional hot mix asphalt concrete.

RECYCLING VARIABLES

Three primary variables govern the amount or percentage of reclaimed material which can be processed through a modified batch or drum mix plant. These three factors include:

1. The temperature to which the new aggregate can be heated,

2. The moisture content of the reclaimed material, and

3. The discharge temperature of the recycled hot mix.

In general, the three factors are more important when producing a recycled material in a batch plant compared to a drum mix plant operation.

Theoretical calculations and actual project experience indicate that there are maximum amounts of reclaimed material which can be recycled in each type of plant. Depending on the values of the above listed variables, up to 50% reclaimed material can be processed in a modified batch plant. For modified drum mix plants, the upper limit for the reclaimed material is approximately

70%, with the remaining 30% of the total aggregate weight consisting of new aggregate. As the moisture content of the reclaimed material increases, and as the required discharge temperature of the recycled mix increases, the amount of reclaimed material which can be processed decreases (if air pollution control regulations are to be met).

BATCH PLANT RECYCLING

The recycling of reclaimed asphalt concrete particles can be accomplished using a modified asphalt batch plant. The process used to recycle the reclaimed or salvaged material is described as the Mixer Heat Transfer Method. The method, first attempted in 1976 on a recycling project in Maplewood, Minnesota, is also sometimes known as the Maplewood Method or the Minnesota Method of pavement recycling.

For batch plant recycling, the moisture content of the reclaimed material is the most important variable. An increase in this moisture content can cause a significant decrease in the temperature at which the recycled mix is discharged from the pugmill and/or a decrease in the proportion of reclaimed asphalt which can be used in the recycled hot mix. In addition, as the reclaimed material moisture content increases, an increase in water vapor and particulate emissions occurs in the batch plant weigh hopper and pugmill area. Thus it is very beneficial to keep the moisture content in the reclaimed asphalt mixtures as low as possible when the material enters the batch plant.

BATCH PLANT OPERATION

The operation of an asphalt batch plant used to produce recycled asphalt concrete mixtures can be divided into two parts. The first process includes the heating and drying of the new aggregate. The second process involves the handling of the reclaimed material and the introduction of this material into the plant weigh hopper.

New Aggregate Processing. New, uncoated aggregate, both coarse and fine, is processed through the asphalt concrete batch plant in a normal manner. The new aggregate is conveyed into the dryer from the cold feed bins. In the dryer, it is superheated to temperatures as high as 600° F, depending on the characteristics of the reclaimed material with which it will eventually be mixed. From the dryer, the superheated aggregate is carried up the hot elevator to the top of the batch plant tower. As the very hot material passes over the screen deck, the aggregate is divided by size and passed into the hot storage bins. The material is weighed out of the hot bins, one bin at a time, as it enters the plant weigh hopper. At this point, the superheated new aggregate is joined by the reclaimed material which enters the weigh hopper by a different flow pattern. (See Figure 1)

Reclaimed Aggregate Processing. The reclaimed aggregate is recovered from its stockpile, usually by a front end loader, and placed in a small capacity, steep-sided cold feed bin. From this bin, the salvaged material is carried by a belt conveyor or bucket elevator directly to the plant weigh hopper. At this point, the reclaimed aggregate is treated as another aggregate to be proportioned, by weight, into the mix. The reclaimed material is usually put into the weigh hopper last, after the new aggregate from the hot bins has been weighed in, in order to minimize the buildup of this material on the sides of the weigh hopper.

Heat Transfer and Mixing. The transfer of heat from the superheated new aggregate to the ambient temperature reclaimed aggregate begins in the weigh hopper. Because the reclaimed aggregate lies on top of the new aggregate, and because the two materials reside together in the weigh hopper for only a short period of time, most of the heat transfer occurs after the weigh hopper is emptied into the batch plant pugmill.

In the pugmill, the new asphalt cement and/or recycling agent is sprayed on the combination of new and reclaimed material. The dry mix time, wet mix time, and total cycle time are usually unaltered from normal hot mix production times. The transfer of heat from the superheated new aggregate to the reclaimed aggregate takes place throughout the mixing process. When the pugmill gates open to discharge the recycled mixture, the heat transfer is completed and the mix is ready to be hauled to the paving site to be placed and compacted.

NEW AGGREGATE TEMPERATURES

In a batch plant recycling operation, the contractor is primarily concerned with the temperature to which the new aggregate has to be heated in the dryer. This temperature is governed by three main variables, including (1) the moisture content of the reclaimed material, (2) the recycled mix discharge temperature, and (3) the ratio or proportion of reclaimed material to new aggregate.

Table 1 illustrates the effect of these variables on the temperature to which the new aggregate has to be heated:

* As the moisture content of the reclaimed material increases, the required temperature to which the new aggregate must be heated increases significantly,

* As the discharge temperature of the recycled mixture from the batch plant increases, the temperature to which the new aggregate must be heated also increases, and

* As the proportion of reclaimed material in the recycled mixture increases, the temperature to which the new aggregate must be heated increases dramatically.

As an example of the use of Table 1, suppose a contractor is operating a modified batch plant during a dry, summer season. The moisture content of the reclaimed material setting in a stockpile is only 1%. The recycled mix is required to contain 20% reclaimed asphalt and the mix discharge temperature must be at least 240° F. From Table 1, Part A, the temperature to which the new aggregate would need to be heated is 315° F.

Suppose the same contractor is now producing a recycled mixture in the fall, during a rainy period. The moisture content of the reclaimed material stockpile is measured at 5%. The required mix discharge temperature is 280° F, and the mix must contain 40% salvaged material. Now the temperature to which the new aggregate would need to be heated has increased to 630° F, as shown in Table 1, Part C.

For most batch plant dryers, however, 600° F is a practical upper limit to which the new aggregate can be heated without shortening the life of the dryer. In the latter example, in order to protect the dryer life, the contractor has several options. He can decrease his mix discharge temperature or reduce the amount of reclaimed material being used in the recycled mix in order to decrease the required new aggregate temperature below 600° F. A better solution, in most cases, would be for the contractor to keep the moisture content of the reclaimed aggregate as low as possible, perhaps by keeping the reclaimed material stockpile covered.

BATCH PLANT MODIFICATIONS -- NEW AGGREGATE PROCESSING

Aggregate Dryer. The new aggregates needed for the recycled mixtures, both coarse and fine, are conveyed to the batch plant dryer from the cold feed bin, as shown in Figure 1. In the dryer, this aggregate is heated or superheated to the required heat transfer temperature. In most standard batch plants, the maximum temperature to which the aggregate can be heated is approximately 600° F.

Because of these extremely high aggregate temperatures, and because of the reduced volume of aggregate flowing through the dryer compared to normal hot mix asphalt concrete, some changes may be needed to the dryer flights. It is particularly important that an adequate veil of aggregate be kept in front of the burner flame at all times. The high temperatures may require some increased maintenance on the inside of the dryer, especially on the flights on the discharge end of the dryer.

At the end of each production cycle, the dryer drum should be allowed to run empty for a reasonable cooling down period after production shutdown. This cooling down period will protect against possible warping of the dryer shell and its internal parts.

Dryer Exhaust System. Because of the superheating of the new aggregate in the dryer, the dryer exhaust gas temperatures can be higher than normal. Extreme exhaust gas temperatures can be prevented by proper arrangement and maintenance of the dryer flights. For plants with wet wash air pollution systems, the high exhaust gas temperatures present no particular problems.

For asphalt batch plants equipped with a fabric filter or baghouse, extremely high exhaust temperatures could damage the bags. Most baghouses use Nomex bags. If the gases entering the baghouse are continuously above 400° F, the bag life will be shortened. At exhaust gas temperatures over 450° F, the deterioration of the bag material would be greatly accelerated. Steps should be taken to keep the temperature of the exhaust gas entering the baghouse below 400° F.

Hot Elevator. Upon discharge from the dryer, the superheated aggregate is carried up to the top of the batch plant tower by the hot elevator system. No problems should be encountered during the conveying operation.

<u>Screen Deck</u>. The superheated aggregate passes from the hot elevator over the batch plant screens. No problems should be encountered during the screening operation unless the screen bearings are located inside the dust housing. If so, excessive temperature buildup could occur in these bearings. Lubricants designed for higher than normal temperatures should then be used in these bearings.

<u>Hot Bins</u>. To prevent excessive temperature drop of the superheated aggregate, consideration should be given to insulation of the outside of the hot bins. The insulation would reduce the high radiation loss while the new aggregate was in the plant hot bins.

<u>Asphalt Cement System</u>. No changes are needed to the asphalt cement delivery system except if a recycling agent is to be added to the asphalt. The point of discharge of the recycling agent, either into the asphalt cement line or directly into the pugmill, depends on the requirements for each individual agent.

BATCH PLANT MODIFICATIONS -- RECLAIMED MATERIAL PROCESSING

<u>Reclaimed Material Size</u>. Asphalt concrete materials are removed from the roadway using two primary methods -- cold planing or pavement scarification and breakup. The reclaimed material generated by the cold planing method is usually of a proper size to be recycled at the completion of the milling operation. Reclaimed material coming from a complete breakup of the old pavement will usually consist of a combination of large chuncks and some fine particles. The chunks of asphalt concrete should be passed through a crusher before stockpiling. The maximum size of the reclaimed material should be less than 2" inches in order to allow the material to be completely broken down in the batch plant pugmill.

<u>Reclaimed Material Stockpile</u>. The amount of reclaimed material stored in a stockpile for use in recycling should be kept to a minimum to prevent moisture buildup in this material. Some reconsolidation of the reclaimed material while in the stockpile can be expected, especially if the old asphalt concrete is rich in binder content and the ambient temperature is high. Both rubber tire and crawler front end loaders have been used to remove the reclaimed material from the stockpile, but the use of loader buckets equipped with teeth is recommended to help breakup any reconsolidated chunks of reclaimed material.

<u>Cold Feed Bin</u>. The cold feed bin used with the reclaimed material as shown in Figure 1, should have a relatively small capacity to prevent reconslidation of the reclaimed material and bridging of the bin discharge opening. The sides of the bin should be steep, and the opening at the bottom of the bin should be long enough and wide enough to allow for easy discharge of the reclaimed materials. Vibrators should not be used on the bin.

Belt feeders have been used under the reclaimed material cold feed bin. These should be fairly wide compared to the overall bin width. The actual conveyor capacity needed would depend on the characteristics of each particular batch plant. The conveyor capacity should be great enough to put the required amount of reclaimed material into the weigh hopper without delaying the batching-mixing process.

Because the conveyor will be continually starting and stopping during the charging operation, a special, heavy-duty motor may be needed to power it. If a special motor is not used, a hydraulic or clutch-type mechanical drive motor might be used to permit continuous running of the power unit. In addition, the conveyor will require a backstop or anti-rollback device to prevent the reclaimed material from sliding backward on the belt. The charging conveyor should be interlocked with the feeder conveyor under the cold feed bin.

If space is limited at the plant site, a vertical or inclined bucket elevator may be needed to carry the reclaimed material to the weigh hopper. Since the elevator should be operated on a continuous basis, a surge bin, located next to the weigh hopper needs to be used. The size of the surge bin must be great enough to hold the required volume of reclaimed material delivered by the elevator during the plant mixing cycle. The surge bin should have very steep sides and should be fitted with a high speed conveyor to deliver the reclaimed material to the weigh hopper. If a surge bin is not used, the bucket elevator must be powered by an oversized, special type motor to allow for start-stop operation.

<u>Weigh Hopper</u>. The entrance chute into the weigh hopper for the reclaimed material should be as steep as possible to prevent this material from hanging up in the chute. In addition, the chute should be of constant width and not narrow down near the lower end. The chute needs to be equipped with a counterweighted draft gate, kept in the closed position except when the reclaimed aggregate is being fed in, in order to prevent the escape of fugitive dust when the new aggregate is being weighed. Finally, the entrance chute should be positioned so as to deposit the reclaimed material as close as possible to the center of the weigh hopper, so that all the reclaimed material can be emptied into the hopper.

<u>Weigh Hopper and Pugmill Emissions</u>. When the reclaimed material is deposited on top of the superheated new aggregate in the weigh hopper, and when the two materials are mixed together in the pugmill, emissions of both moisture and dust can occur. These emissions are caused by the escape of the moisture in the form of steam from the reclaimed material.

The rate of release of this steam vapor can be quite large. As an example, if 3,000 pounds of reclaimed material, containing 3% moisture, is placed in a 6,000 pound batch plant pugmill, the rate at which steam will be given off in a 5 second release time will be at approximately 30,000 cubic feet per minute.

A real problem can exist when the release of steam carries dust particles out of the weigh hopper and pugmill. The best way to control these particulate emissions is to reduce the moisture content in the reclaimed material and/or to reduce the proportion of reclaimed material in the recycled mixture. Another way to approach the problem is to adequately vent the weigh hopper and pugmill to the atmosphere or put it into a plant air pollution system. In this latter case, the vent has to be of sufficient size to allow for both the escape of the steam and for the collection of the dust particles which drop out of the vapor stream as the vapor velocity decreases. The size and type of vent will depend on each particular contractor's plant set up.

DRUM MIX PLANT RECYCLING

NEW AGGREGATE PROCESSING

Five major components comprise a modern, conventional drum mix plant. These five are: (A) a multiple bin cold feed system, (B) a charging conveyor for feeding the new aggregate into the drum mixer, (C) the drum mixer, (D) a hot mix surge system, and (E) a dust collection system. These components are shown in Figure 2.

For conventional hot mix asphalt concrete mix production, the coarse and fine aggregates are proportioned out of the cold feed bins onto a variable speed collecting conveyor running underneath the bins. The combined material is then transferred to the charging conveyor. On the way up the conveyor, the aggregate passes over a belt scale consisting of a weigh idler and a belt speed sensor. This "weigh bridge" setup measures the amount of material being fed into the drum mixer.

Next the aggregate enters the drum itself. The drum mixer uses a parallel flow principle to heat and dry the aggregate. This means that the exhaust gases from the burner flame move in the same direction -- down the drum -- as the aggregate material does. This is in contrast with a regular aggregate dryer on a batch plant which uses a counter-flow method of heating and drying (the cold, wet aggregate flows toward the burner flame, against the exhaust gas stream).

The interior of the drum mixer is divided into two zones. The front half of the drum is the radiant heating zone, where the cold, wet aggregate is heated and dried. In this zone, the aggregate is subjected to radiant heat from direct contact with the burner flame, convective heat from exposure to the hot exhaust gas stream and conductive heat from one aggregate particle coming in contact with another particle. Special flights inside the drum move the aggregate away from the burner flame and build a veil of aggregate in front of the flame. Optimum density of the aggregate veil maximizes the heat transfer process and the removal of the moisture from the coarse and fine aggregates.

The rear or lower half of the drum is the convection coating zone. Heat transfer in this part of the drum takes place primarily by convection and conduction. Asphalt cement is introduced into the drum through a pipe entering from the rear of the drum. Moisture released from the aggregate causes the asphalt cement to expand and foam. The aggregate particles tumble through the foaming asphalt cement and are coated in the process. The aggregate veil created by the flights in the upper half of the drum mixer protects the asphalt cement and asphalt coated particles from exposure to the burner flame, thus preventing premature hardening of the asphalt cement. The remaining flights in the drum allow the asphalt coated aggregate to continue to be heated until the desired mix discharge temperature is obtained.

Upon discharge from the drum mixer, the asphalt concrete mixture is carried up a drag slat conveyor or vertical elevator into a surge and/or storage silo. Because a drum mix plant manufactures mix on a continuous basis, a silo is required to temporarily store the asphalt concrete until it can be loaded on a hauling vehicle. Either a wet collector or a fabric filter can be used for dust collection.

RECLAIMED AGGREGATE PROCESSING

Combined Aggregate Feed. Two methods are currently used in the industry to introduce the reclaimed aggregate into the drum mix plant. The first, promoted by one equipment manufacturer, uses one charging conveyor to feed both the new aggregate and the reclaimed aggregate into the burner end of the drum mix plant. The process, termed the low temperature convection heating method, uses a flame diffusing combustion chamber to reduce the temperature of the burner flame and exhaust gases at the point where they come into contact with the combined new and reclaimed aggregate.

Asphalt cement and/or recycling agent is added to the blended material in conventional fashion. The new aggregate, reclaimed aggregate, and binder are mixed in the drum. The asphalt concrete mixture is discharged from the rear of the drum and carried to a surge silo.

Split Aggregate Feed. The second method of manufacturing a recycled asphalt concrete mixture in a drum mix plant uses a split feed process. In this method, the new aggregate is handled and processed in a normal manner, through the burner end of the drum mix plant. The reclaimed material, however, is fed into the plant through a separate cold feed system, with the point of entry of the material just beyond the midpoint of the length of the drum. This entry position is shown in Figure 3.

The new aggregate, introduced into the radiation zone of the drum mix plant, is heated and dried. Depending on the relative proportions of new and reclaimed aggregate used in the recycled mixture, the new aggregate is superheated to a temperature between 300° F and 600° F by the time it reaches the midpoint of the drum. The combustion gases from the burner are cooled by the new aggregate to a 800° F - 1,000° F range by the time the gases reach the drum midpoint.

The reclaimed material is introduced into the plant from a separate small capacity, steep-sided cold feed bin. A charging conveyor, complete with a weigh bridge system, feeds this material into a rotary inlet and deposits it in the bottom of the drum, in a short area where no flights are located. Heat transfer begins to take place between the new aggregate and the reclaimed material. The new asphalt cement and/or recycling agent is pumped into the drum and mixed with the combined aggregate at this point in the process. Heat transfer between the new and reclaimed aggregate continues, by convection and conduction, as the blended material moves down the drum to the discharge end. The recycled material is then transferred to the surge bin by a vertical hot elevator or drag slat conveyor.

NEW AGGREGATE TEMPERATURES

If the amount of new aggregate used in the recycled asphalt concrete mixture is more than about half of the total aggregate weight, enough new material will be introduced into the burner end of the drum mix plant to create an adequate veil of aggregate in front of the burner flame and cool the exhaust gases before they come in contact with the reclaimed material farther down the drum. If, however, the quantity of new aggregate is reduced as the amount of reclaimed material is increased to more than about half of the recycled mix, some changes must be made in the drum mix plant operation to prevent the generation of blue smoke when the hot exhaust gases come in contact with the asphalt coated reclaimed material.

If the exhaust gas temperatures are high enough (over 800° F - 1,000° F) when they meet the reclaimed aggregate, the asphalt from the surface of the reclaimed material will evaporate. This evaporated asphalt recondenses into an aerosol mist. The mist, or blue smoke, has particle sizes in the range of 0.1 to 0.5 microns. No practical methods have been developed to catch these very tiny hydrocarbon particles.

To prevent the generation of blue smoke during the recycling operation, the new aggregate and exhaust gas temperatures must be controlled. A balance must be reached between the following variables: (1) the moisture content of the reclaimed material, (2) the recycled mix discharge temperature, (3) the ratio or proportion of reclaimed material to new aggregate, and (4) the recycled mix production rate (tons per hour). These four variables have to be balanced in order to meet environmental requirements and prevent the asphalt cement on the reclaimed aggregate particles from vaporizing.

Higher new aggregate temperatures will be necessary as: (1) the moisture content of the reclaimed material is increased, (2) the recycled mix discharge temperature is increased, and (3) the amount of reclaimed material in the recycled mix is increased. The drum mix plant production rate may have to be altered -- either increased or decreased, depending on the values of the other three variables -- in order to balance the heat transfer process and prevent air pollution problems.

DRUM PLANT MODIFICATIONS -- NEW AGGREGATE PROCESSING

For the production of recycled asphalt concrete mixtures containing lesser amounts of reclaimed aggregate, no changes need to be made to the new aggregate feed portion of a split feed drum mix plant. Enough new aggregate is used to create an adequate veil of material in front of the burner flame to accomplish the necessary heat transfer.

As the proportion of new aggregate in the recycled mix is reduced, however, the remaining new aggregate must be heated to a higher temperature in order to store enough heat to increase the temperature of the reclaimed material to the desired level. A lower percentage of new aggregate results in a reduced veil that is less efficient in lowering the temperature of the exhaust gases. The result is high gas temperatures at the mid-length of the drum and the possible production of blue smoke.

If the variables mentioned above can not be altered enough to eliminate the blue smoke problem at the point where the reclaimed material is introduced into the drum mixer, changes may have to be made in the flight design of the plant. The type of changes necessary, however, would depend on the characteristics of each individual plant and operating mode. The important requirement is that a dense veil of new aggregate be created in front of the burner flame.

DRUM PLANT MODIFICATIONS -- RECLAIMED MATERIAL PROCESSING

Reclaimed Material Handling. The requirements for sizing the reclaimed material, storing it in temporary stockpiles, and feeding it into the drum mix plant from a cold feed bin are similar to the requirements for a batch plant recycling operation. These operations were described in detail previously.

Rotary Reclaimed Material Inlet. The recycling modifications for a drum mix plant consist primarily of the installation of a center feed, rotary inlet system into the drum near its midpoint. This is shown in Figure 3. The rotary charging system uses a set of chutes to convey the material through the shell of the drum mixer. The number and size of the chutes depends on the capacity of the plant.

The reclaimed material flows by gravity into the drum, in an opposite direction from the rotation of the drum. This material is deposited at the bottom of the drum where it mixes with the superheated new aggregate. Asphalt cement and/or recycling agent is introduced into the drum immediately behind (downstream) of the reclaimed aggregate rotary inlet. The three materials -- new aggregate, reclaimed aggregate, and asphalt -- are then mixed and the recycled mixture heated to the required discharge temperature as it moves down the lower half of the drum mixer.

SUMMARY

Both new and existing batch and drum mix asphalt plants can be modified to produce recycled asphalt concrete mixtures. For typical batch plant recycling operations, up to 50% reclaimed material can be introduced into the weigh hopper. For split feed rotary inlet drum mix plants up to 70% reclaimed material can be incorporated into the recycled mixture.

The primary variables which govern the amount of reclaimed material which can be processed through a modified batch or drum mix plant include: (1) the maximum new aggregate temperature, (2) the moisture content of the reclaimed material, and (3) the discharge temperature of the recycled hot mix.

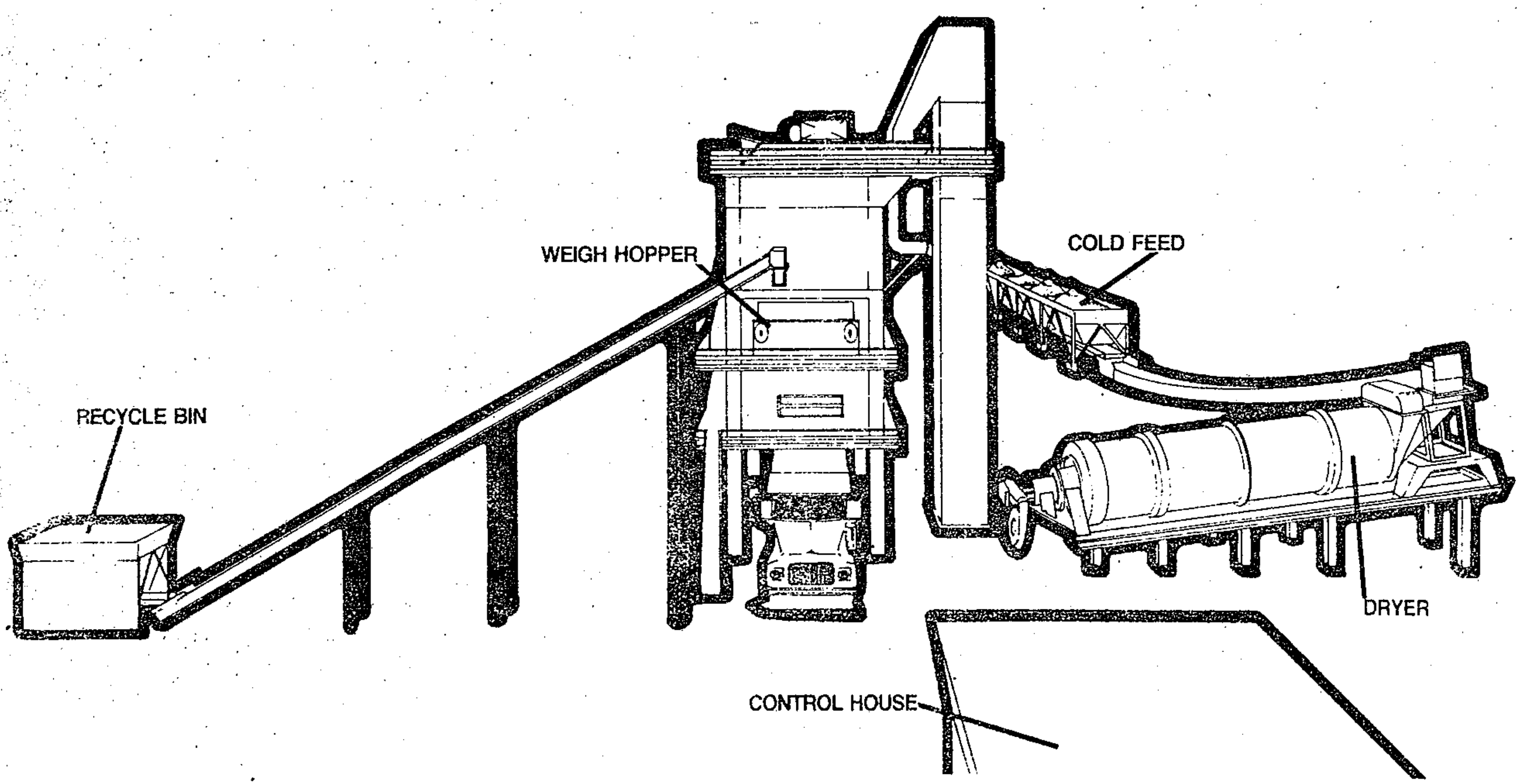

Figure 1: Asphalt Batch Plant with Reclaimed Material Processing System.

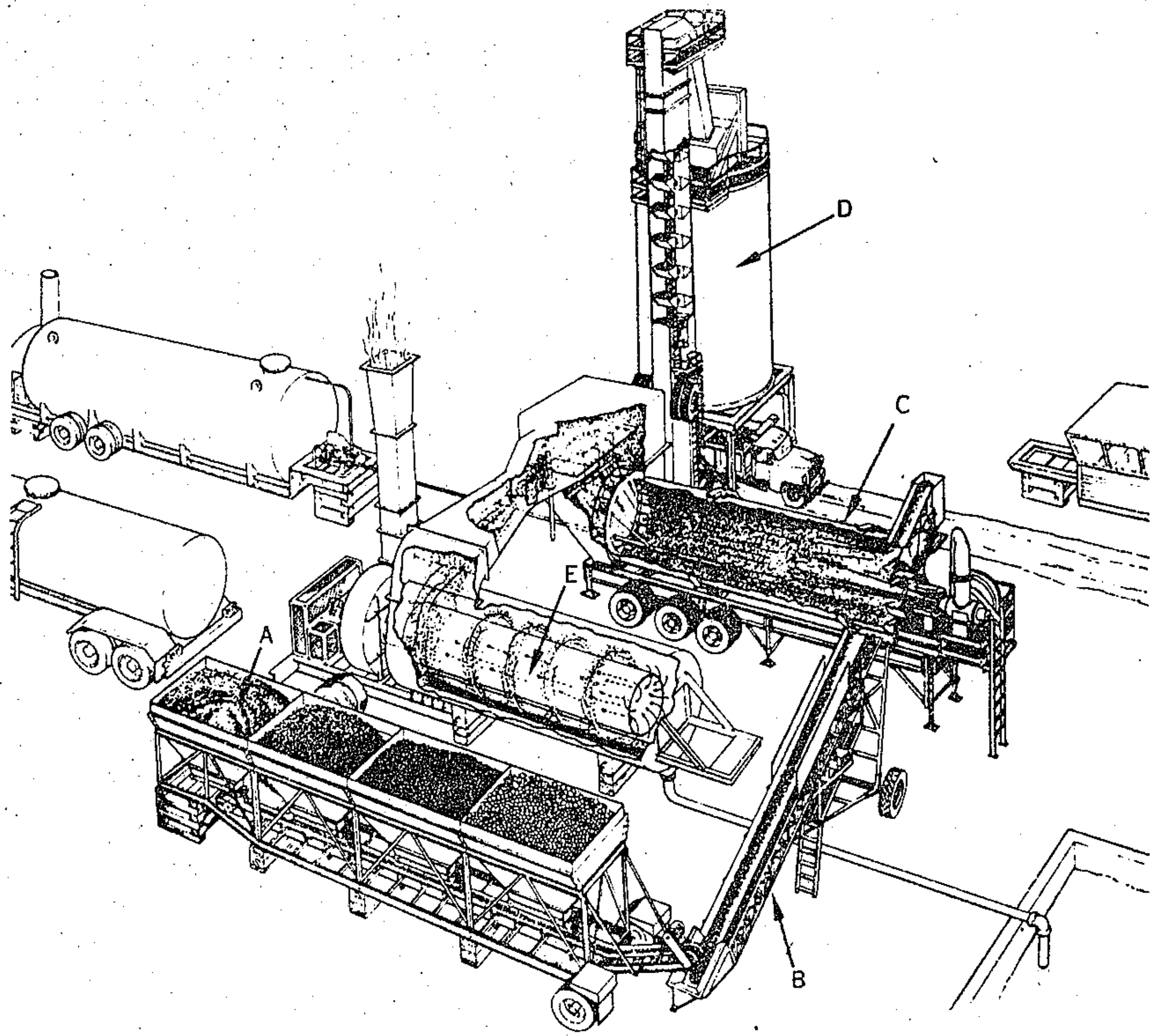

Figure 2: Components of a Typical Drum Mix Plant. A. Cold Feed Bins, B. Charging Conveyor, C. Drum Mixer, D. Surge Silo, and E. Dust Collection System

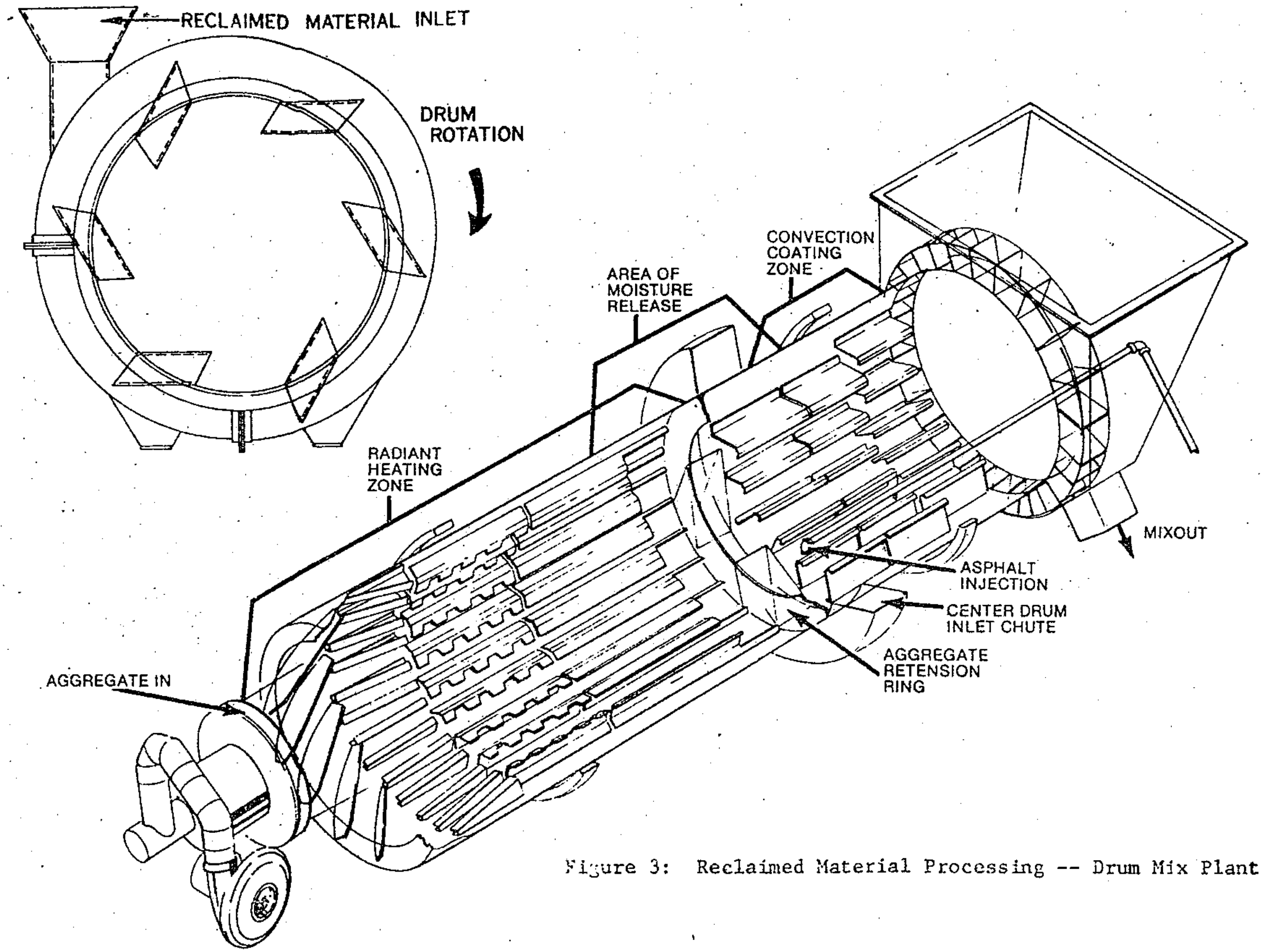

Figure 3: Reclaimed Material Processing -- Drum Mix Plant

ARIZONA CASE HISTORIES

OF

CENTRAL PLANT RECYCLING

by

Rowan J. Peters
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ARIZONA DEPARTMENT OF TRANSPORTATION
Materials Section

For presentation at the FHWA and Caltrans sponsored Asphalt Concrete Recycling Seminars, September 15 - 18 in Sacramento and Long Beach, California.

ARIZONA CASE HISTORIES

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CENTRAL PLANT RECYCLING

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INTRODUCTION

Federal, state and local agencies are currently faced with a number of very critical problems which include the reduction in available funds due to inflation, a declining tax base, and declining revenue from taxes on fuel. The availability of material sources has been reduced due to environmental limitations, zoning restrictions, and increased haul distances. The availability of trained personnel has declined due to fiscal constraints and labor problems. The availability of fuel and asphalt has also been seriously tested in past months.

A possible relief to these problems is the serious consideration to re-use existing in-place materials by recycling for construction and maintenance needs. By recycling, we conserve energy and materials (aggregates, binders, guardrail, etc.) and are able to preserve the pavement geometrics and environment.

For several years the Arizona Department of Transportation has had to find ways to extend its maintenance monies. Attempts were made to rejuvenate pavement surfaces by applying recycling agents as fog seals. This strategy was successful to some degree, in healing cracks or reducing the further development of cracks. The department then ventured into surface recycling (heater scarification) in attempts to further preserve its pavements.

Pavements that are too greatly distressed to be benefitted solely by surface recycling, due to surface conditions etc., are considered for hot-mix recycling and more recently for cold-mix recycling.

SELECTION AND DESIGN

If an asphaltic concrete pavement is so badly cracked, stripped or ravelled that it is no longer acting as a monolithic unit, it must be assumed to have little more structural value than a good granular base material. To overlay such a pavement would mean to leave all of that expensive bituminous material solely as a base course and not fully realize its potential. Recycling all or part of this pavement could reduce or eliminate the required overlay thickness. Removing and recycling the in-place bituminous material would also provide access to base materials which, if required, could undergo stabilization treatment. Even if the existing roadway is not so extensively deteriorated, surface recycling will heal large cracks and make reflective cracking through the overlay less likely. What level of deterioration warrants consideration of hot recycling?

In Arizona we estimate the amount of cracking in a pavement surface by comparing the surface to a series of photos which represent the percentage of cracks in a number of 1000 square foot samples (the "crack index")[1]. Each picture shows a roadway from an angle similar to that of an observer. Currently, we consider surface recycling if the crack index is greater than 10%, and more extensive recycling (hot or cold) if the crack index is over 40%. Figure 1 shows the photos corresponding to crack indexes of roughly 10% and 40%.

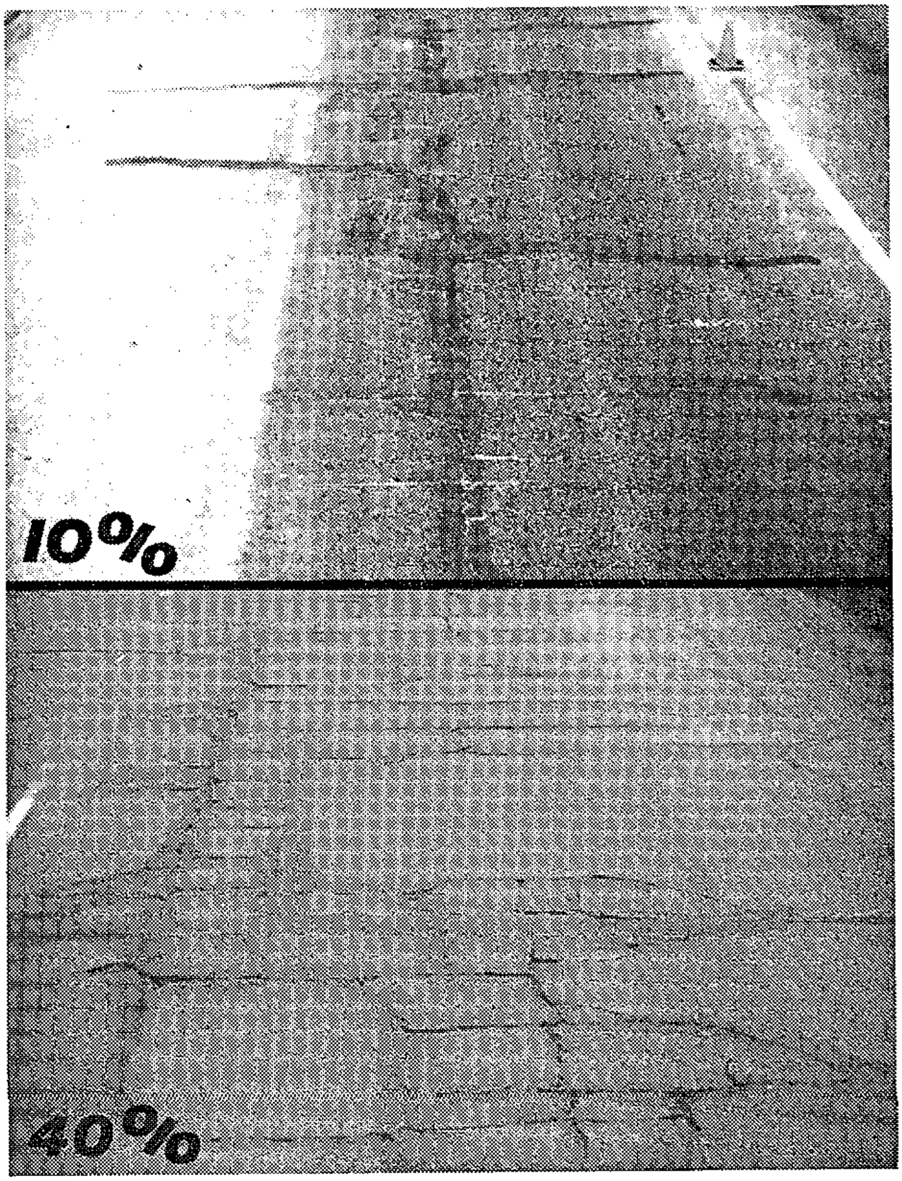
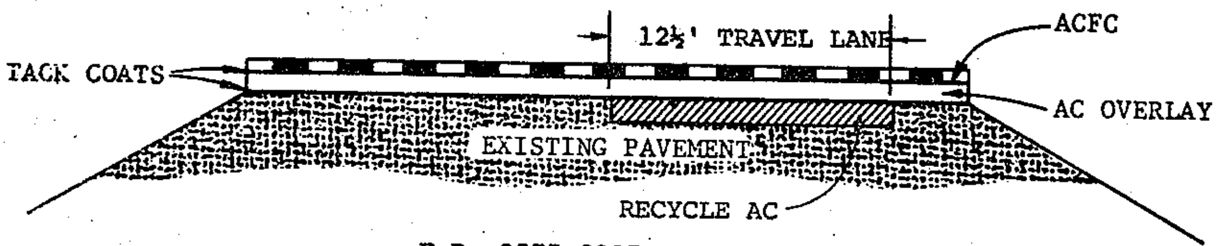


FIGURE 1

Once recycling has been established as one possibility, further measures can then be taken to determine whether it should be the chosen strategy.[2] The first thing to determine is whether or not the existing bituminous material will even make a suitable recycle mix. Some older roadways have undergone years of seal coating, patching, and other maintenance, resulting in a top layer consisting of a variety of materials ill suited for recycling. Because of that, heater-scarification may have to be ruled out, and in the case of deeper recycling, provision would have to be made for possibly removing the surface material prior to recycling the remaining A.C. Other roads may have been built using aggregates which are considered undesirable. Finding out if the material is recycleable involves consulting pavement history data, or taking core samples, or most likely a combination of the two. Cores serve the dual purpose of providing information about the pavement for the design decision process, and providing material samples for use by a laboratory in establishing the recycle mix design. Less obvious features of a pavement, such as binder properties may contribute to making recycling impossible, but will not show up until a mix is tried.

After determining that it is possible to produce an acceptable recycled product, specific design alternates involving recycling can be developed. Is it necessary to heater-scarify all lanes? Should the existing A.C. be recycled full-depth, or should only a portion of it be milled and recycled? Is a combination of surface and deep recycling the best strategy? Since there is no specialized design procedure established for recycling strategies, the answers to these questions must be obtained by consideration of pavement needs and the costs of the various alternates as they compare to that of a "conventional" overlay design. There are no nomographs to consult which will tell you what to recycle, if anything. Often the amount of funds available for a project is limited to the cost of a conventional design, and recycling alternates of comparable cost can be derived. A project using a combination of recycling techniques was built in Arizona in 1978 for instance. The project consisted of rehabilitating 16 miles of interstate roadway on I-8 30 miles west of Gila Bend. Consideration of pavement condition and funding availability led to the design depicted in Figure 2, as shown below. For a complete chronology of other projects see Appendix A.



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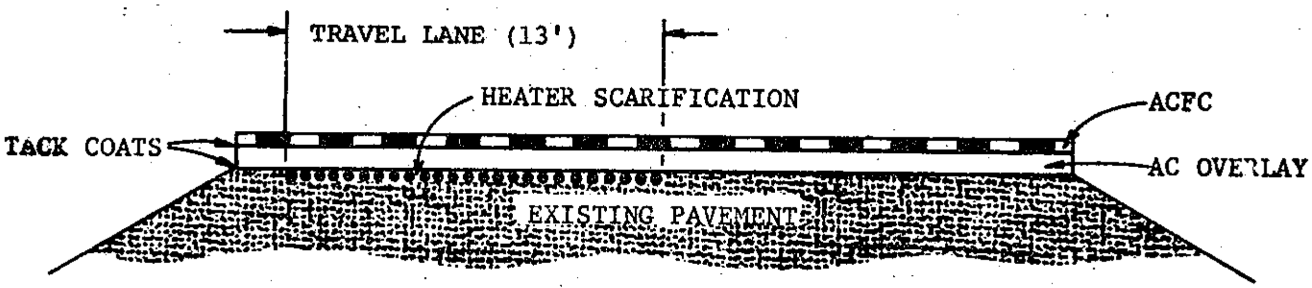

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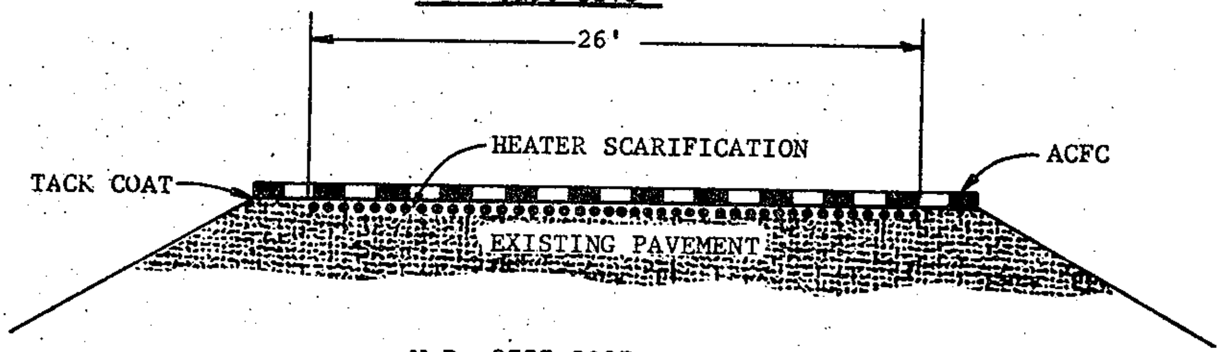

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CENTRAL PLANT HOT MIX RECYCLING

General Discussion

When central plant, hot mix recycling of asphaltic pavements first emerged as a possible or valid strategy to an asphaltic concrete pavement rehabilitation problem, a hard look at the process was taken. We had already started stockpiling salvaged asphaltic concrete pavement material in anticipation of recycling in the future.

After review of a recycle operation near Las Vegas, Nevada, in November 1976 it became apparent that several problems posed a threat of stifling the whole concept of recycling. These problems were mainly those involving pollution, production rates, product acceptability and the cost of equipment. In the short five year period to the present time, most of these problems have been minimized.

The properties of a recycled asphaltic concrete mix, when properly designed, should hopefully be equal to or superior to a conventional asphaltic concrete's properties. The mixes produced so far have been as workable as conventional mixes from a construction standpoint. However, a tendency has been to raise recycling oil percentages to ease compaction in lieu of increasing mix temperatures.

Mix design procedures were not changed in designing hot recycling mixes and no disparity between design and actual results has been noted so far. Stability is usually slightly lower as would be expected with high mineral aggregate fines and high asphalt content mixes. Cohesion is usually slightly higher as is common with high asphalt mixes.

General Observations

Since the first production of recycled asphaltic concrete to the present time, several observations have evolved from experience with these materials.

1) In designing recycle mixes, the desired product may be accomplished by aggregate blends, recycling oils, or additives, or combination (see Figure 3). This mix should have the minimum requirements of a virgin asphaltic concrete.

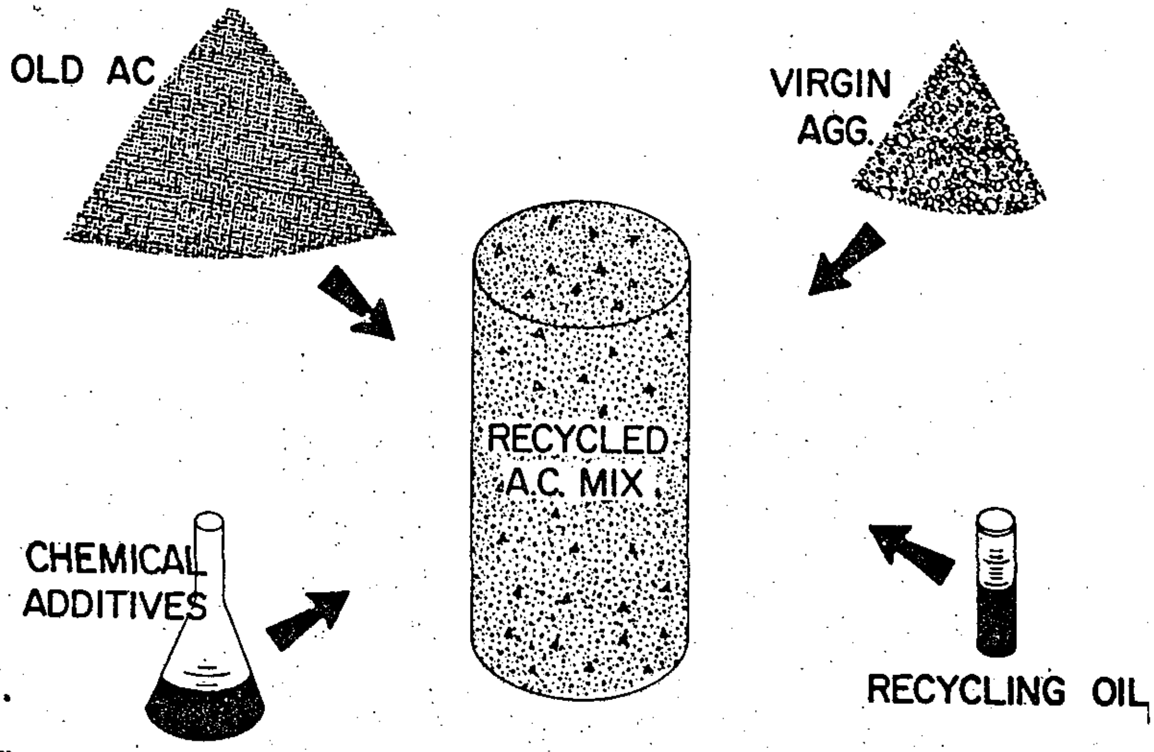

FIGURE 3

2) Designers should make allowances for some contamination of bituminous materials with non-bituminous materials during the ripping and crushing pavement removal process. Degradation of the aggregate during a cold milling pavement removal process should also be considered.

3) Generally the design recycling oil content is 0.2% less than is required for actual construction. The 0.2% difference allows for better workability, however it increases the risk of an unstable or low void mix. Workability should be achieved through higher temperatures if possible.

4) Although lower production rates may result in higher costs per ton, the reduced tonnage from reduced overlay thickness requirements compensates for this total cost.

5) To date, the recycled mixes placed are performing equal to conventional asphaltic concrete mixes.

Case Histories

Bowie Jct. - Safford S 207-904

In the southeastern portion of Arizona, between Willcox and the New Mexico state line, part of the old asphaltic concrete being removed and disposed of on an $8.5 million Interstate highway project, I 10-6(50), was salvaged, crushed, recycled, and used to overlay (5.3 miles) of U.S. 666 from I-10 north to the Graham County line.[3] Approximately (22,000 cubic yards) was salvaged and stockpiled near the south end of the proposed overlay project.

Laboratory testing indicated that blending coarse mineral aggregate with the crushed old asphaltic concrete at a ratio of 20 - 80 percent would give a job-mix formula with the desired gradation, percentage voids in mineral aggregate, and effective voids.

It was determined that the cost of salvaging, hauling, crushing, and stockpiling the old asphaltic concrete was ($1.49/ton). In addition, coarse mineral aggregate was purchased, hauled, and stockpiled, ready for blending with the salvaged asphaltic concrete, for ($2.84/ton).

The design called for the 20 - 80 blend of coarse mineral aggregate and old asphaltic concrete be combined and mixed with approximately 2.2 percent of an AR-2000 paving asphalt and aromatic extender oil blend. Approximately 18 percent of aromatic extender oil, (Dutrex) based on the weight of the asphalt was recommended for the blend.

The project was advertised with a bid opening date of January 7, 1977. As a result of a prebid conference, the requirement that aromatic extender oil and paving asphalt be introduced into the mixer through separate meters was deleted. In addition, after much discussion, air quality standards were relaxed because of the experimental nature of the project. Specifically, the particulate count was waived, and the allowable maximum opacity was 40 percent.

The bid opening was postponed until January 13, 1977, when it was learned that a U.S. patent had been approved for recycling of asphaltic concrete and for the aromatic extender oils used in the process. This delay gave the bidders an opportunity to review the patent and to make provisions, if necessary, in their bids for royalties claimed by Mendenhall, the patent owner.

The initial modificiations to the drum mixer included installation of a special steel alloy "pyro-cone" (6 ft.) in diameter and perforated with (1-in.) holes. The second major modification was the addition of a high-speed underfeed belt. The purpose of this belt was to throw the blended cold-feed material about (3 ft.) into the drum so that the asphalt-coated particles of the crushed asphaltic concrete would be removed from the high temperatures near the inlet end of the drum as quickly as possible.

Another modification was the installation of a meter for blending the aromatic extender oil with the paving asphalt as the two materials were pumped into the asphalt storage tank. This method of metering worked fairly well but for one serious drawback: the percentage of extender oil in the blend of asphalt and extender oil could not be changed with any degree of exactness until the asphalt storage tank was almost empty.

Another important addition was six (0.375-in.) water sprays, three each to two (1-in.) feed lines, for the purpose of adding moisture to the cold-feed material. Each feed line was equipped with a valve and a pressure gauge for adjusting the amount of added moisture to help control emissions from the stack.

The result of the initial production was not satisfactory. Heavy smoke was being emitted from the plant. The mix had a dry, lifeless appearance and lacked cohesiveness; the aggregate coating was not good; and the fine particles had a burned look. The water pressure on the cold-feed was then reduced from (70 to 30 lbs/in^2) and was finally discontinued; there was no apparent change in the opacity of emissions as a result of any changes that were made.

On the second day of operation, the contractor moved the discharge end of the asphalt line in the drum from (10.5 to 12 ft.) from the inlet end of the drum. Several combinations of mix ingredients were tried in an effort to reduce the opacity of emissions but without success. It was apparent from all of these combinations that most of the smoke problem was caused by the burning of the finer asphalt-coated particles. It was soon determined that the plant would not meet the air quality standards for the project unless major changes were made.

A decision was made to further modify the drum mixer. The steel alloy pyro-cone was moved from (6 to 3 ft) from the inlet end of the drum. The burner was moved back an additional (2 ft) from the end of the drum, and a 2 ft. wide steel colar was placed around the circumference of the drum extending toward the burner. The purpose of the modifications was to confine the burner blast and also to produce the effect of moving the cold feed farther away from the burner blast and the high temperature at the inlet end of the drum.

Operations began again on March 22, 1977. Adjustments were made to the exhaust damper and the air-fuel mixture used in the burner. The opacity of emissions still exceeded the allowable 40 percent. In the afternoon, 2 percent moisture was added to the 4 percent stockpile moisture of the blended cold-feed material. The application of this additional moisture considerably reduced emissions. At the end of the day, the addition of moisture to the cold feed was stopped, and emissions increased drastically.

The next day, a number of different production rates were tried. For all rates of production, 2 percent moisture was added to the cold feed. We also began experimenting with different allowable temperatures of the mix at the outlet of the drum. The contractor discovered that, to increase production and maintain allowable opacities, the outlet temperatures had to be reduced.

On the basis of these results, an order for a change in the project contract was initiated to lower the required temperature of the mix at the outlet of the drum. The contractor also agreed to cover the surge hopper and the conveyor belt from the outlet of the drum to the surge hopper to prevent loss of heat from the mix.

As the project progressed, further experimenting was done with temperatures and it was determined that, by lowering the temperature of the mix to between (200° F and 205° F) at the drum outlet, production rates of (324 tons/h) could be achieved without serious smoke problems as long as 2 percent moisture was being added to the cold-feed. Higher production rates might have been achieved, but the ultimate capacity of the exhaust fan for this particular plant was reached at this rate of production.

The gradation consistency of the mix was very uniform. And, with 50 percent aromatic extender oil in the blend of AR-2000 paving asphalt and extender oil, the most desirable mix was achieved with the use of 2.7 percent of this blend composition. The resultant extracted asphalt content was 5.3 percent with a penetration of approximately 64 and a viscosity of around 2180 poises.

Yuma County Line - Gila Bend I 8-2(76)

The original pavement structure was built in 1950 and consisted of 4 inches of select material, 5 inches of aggregate base and 2 inches of mixed bituminous surface.[4] This roadway carried traffic in both directions until 1960 when the westbound roadway was built. The eastbound roadway section was increased by the addition of a 1-1/2 inch overlay at this time. No further work was done until 1970 when the eastbound roadway was sealed with an emulsified petroleum resin flush. The eastbound width is 38 feet consisting of a 4-foot shoulder, a 12-foot passing lane, a 12-foot travel lane and a 10-foot distress lane.

The pavement was block-cracked in the travel lane with some areas at or approaching an alligatored condition. The estimated crack index was 35-40%. The block cracking occurred at approximately 20 feet spacing, transversely across the roadway. In some areas, cracking had deteriorated to alligator cracking and in the worst areas, popouts were occurring due to the alligatoring. Some minor rutting was evident. All types of distress were greater in the travel lane than in the passing lane.

Performance Characteristics

The rideability index as measured by the Mays ride meter averaged 3.1 which indicates a fair ride. The deflection as measured by the Dynaflect indicated an arithmetic mean of .788 mills which is a moderate deflection level. The surface friction as measured by the Mu-meter averaged 58 which is a moderate skid level.

Design Selection

A design section of removing and replacing the 3-1/2 inches of bituminous material in the travel lane and placing a 1-1/4" AC and 1/2" ACFC overlay was selected (see Figure 4) since:

(1) The funds were not available for more than 1-1/4" AC and 1/2" ACFC overlay by the then FHWA funding policies; additional State funds would have to be used.

(2) The major distress was in the travel lane. The passing lane did not justify the same overlay thickness or rehabilitative measures as the travel lane. This design allowed more extensive rehabilitative measures to be performed where they were most needed.

(3) It was desired to evaluate the recycling concept.

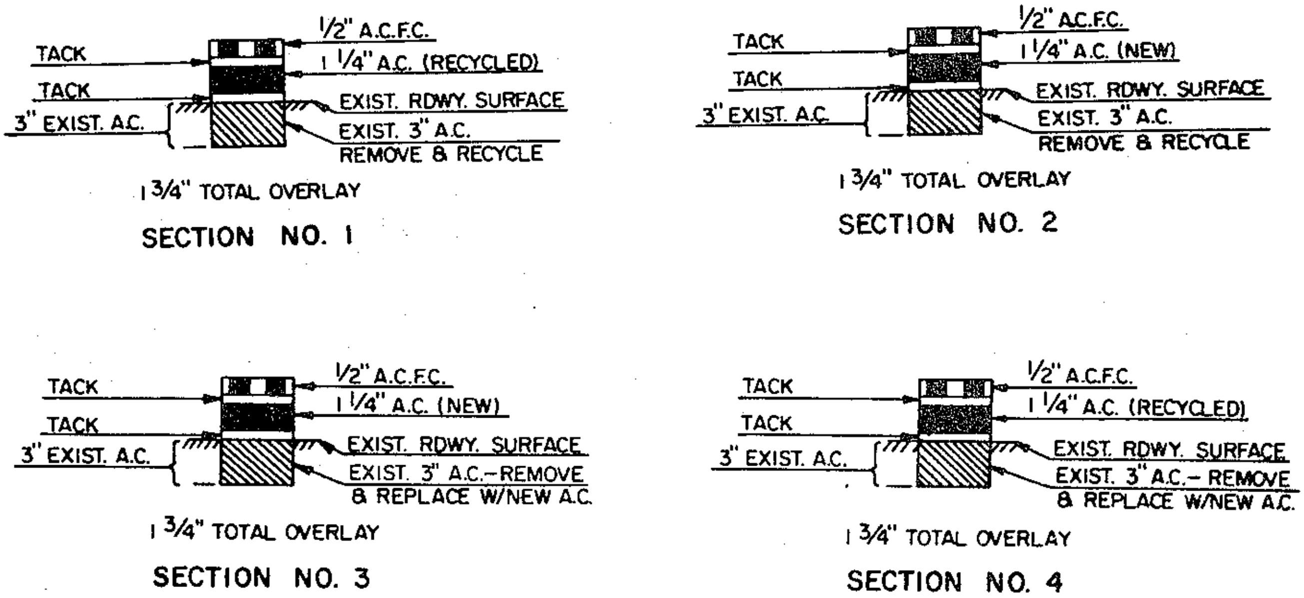

FIGURE 4

Mix Design

In designing the recycle options, three characteristics were examined: the average gradation, void relationships and effect of water on the mix. First, considering the option of using the asphaltic concrete and mixed bituminous surface materials, the average gradation of the samples indicated a 41% pass #8 and 7% pass #200. The #8 value is approximately what is used for the target value for that screen in a conventional asphaltic concrete design. 4% pass #200 is usually specified as a target value, so 7% is high. A coarse aggregate blend was decided against because of past raveling experience with coarse blends. Secondly, void relationships were examined to determine type and amount of asphalt modifier. At the percentage required, the type needed would be a recycling oil comparable to Cyclogen L based on the viscosity of the salvaged materials.

The third characteristic examined was the effect of water on the mix. The mix was tested in accordance with ARIZ 802 (a modification of AASHTO T-165, Immersion Compression). The retention was 35% with a wet strength of 132 psi. The usual requirements for this region are 40% retention and a wet strength of 150 psi. Based on the 5" of annual rainfall, the retention values were accepted.

The second option, using 25% AB and 75% (AC and MBS), was evaluated the same way. The average gradation of the composite increased in pass #200's from 7% to 8% due to the addition of the AB. This factor was undesirable. The void relationships were then examined and 2.5% recycling oil was needed to achieve acceptable results. This factor also was undesirable due to the cost of recycling oil. Next immersion compression tests were run and a retention of 28% and a wet strength of 95 psi were recorded. These results were totally unacceptable. Therefore, the option of using AC and MBS materials or 100% recycle was chosen.

Construction Equipment

During the removal operation, the contractor used a CMI Rotomill milling equipment, type PR-575. The equipment had a cutting width of 9'2" using a rotary drum with 176 cutting teeth. The contractor initially began cutting the full 3 to 3-1/2" depth in one pass. Because of the crack pattern in the pavement, this full depth milling produced large sized pieces of pavement. The contractor thus began to remove in two lifts, the first 2" deep and the second to the interface of the base and the asphaltic material. Because of the depth restriction and the width, it was necessary to make four passes to get the required depth and width. The milling of the approximately 57,200 sq. yd. was accomplished in 137 working hours for an average of 428 sq. yd./hr. The rotomill was equipped with a conveyor belt which loaded the trucks. The trucks then hauled the material to the plant site.

The drum mixer was a Shearer Process, 500 TPH, drum mixer. It was equipped with a dry cyclone collector for use as a primary emission control device. The modifications that the contractor made were, 1) to lengthen the frame in front of the drum mixer, 2) move the burner back, and 3) replace the conventional combustion chamber with a Boeing "Pyro-Cone."

The "Pyro-Cone" consists of a combustion chamber, an extension sleeve with ventilation slots, and a perforated heat shield. This modification increases the distance from the direct flame to the aggregate material. The shield is used to stop the flame and allow only the hot gases to pass so as not to ignite the asphalt in the old mix.

Production rates ranged from 250 to 350 TPH with optimum results at around 275 TPH. Aggregate temperature recorded by the drum dryer pyrometer indicated temperatures ranging from 190 to 275° F. The best product was produced when the plant was running @ 200° F and 250 to 275 TPH. The plant generally produced within the temperature specification. Density was no problem, ranging from 95 to 98% of theoretical maximum density.

Performance of all Projects

In Table 1, shown on next page, is a listing of average Present Serviceability Ratings and percent cracking for each of eleven projects wherein hot recycling was performed. Since the oldest projects are only in the four to five year age category it was doubtful that any meaningful data could be available at this point. All projects basically are showing comparable levels of performance today as that which existed following construction.

One project has had observable rutting; however, it is not quite known whether the problem can be associated strictly to the recycled mixture since new asphaltic concrete on the same project has shown similar signs of rutting. Possibly new as well as recycled mixtures placed under conditions of high early loading are candidates for premature densification and subsequent rutting.

PROJECT	PRESENT SERVICEABILITY RATING *			% CRACKING **		
	PRIOR CONST	AFTER CONST	1981	PRIOR CONST	AFTER CONST	1981
S 207-904	3.0	3.4	3.4	1%	0%	0%
I 8-2(76)	3.7	4.3	3.9	20%	0%	0%
F 057-1-901	2.7	3.6	3.6	20%	0%	0%
I 10-6(78)	3.5	4.2	3.9	14%	0%	0%
I 10-4(66)	3.0	3.8	3.5	14%	0%	0%
I 10-4(68)	2.9	3.8	3.7	10%	0%	0%
I 17-1(123)	3.1	3.5		7%	0%	0%
FRI-I 40-2(86)	2.8	3.9	3.9	30%	0%	0%
I-IR 10-6(84)	3.4	4.0	4.0	32%	0%	0%
IR-I 17-2(85)	3.2			4%	0%	0%
FI-I 17-1(136)	3.6	3.9	3.9	7%	0%	0%

*1973 Special Report 133
Highway Research Board

**1978 Association of Asphalt
Paving Technologists

TABLE I

We have observed the tendency for recycled mixtures to change properties with time as recycling agents begin their diffusion into the old aged asphalt. On one project this transformation developed to a point that eventually instability resulted and the removal of the recycled material was required. In that case, additional recycling agent was added to liven the mixture and facilitate compaction. However, as the agent continued to work on the aged asphalt the physical properties of the mixture changed and instability developed.

In the observation of deflection data developed prior to and following construction, it would appear that little can be said regarding differences in "reactions" between new and recycled mixtures. How the data relates to such performance elements as cracking, ride and structural adequacy is not known at this time since the time following construction is so recent.

General Observations

In the observation of laboratory design methods as they relate to actual construction, it would appear that the combination of features from both the Hveem and Marshall methods should be explored. For instance, the Marshall flow value seems to predict the potential for instability better than the Hveem stability. On the other hand the Hveem compacted specimen appears to relate better to obtainable compaction and particle orientation than does the Marshall specimen. The problem would appear to be the need to establish a design method which relates to construction and which also considers the effect of the diffusion of recycling agents into the old asphalt. The Hveem method would appear to be the better overall method with additional input from Marshall method as required.

Another observation would appear to be that the optimum combination of new material with recycled material is a function of many factors not least of which is the effect of recycling agents on the aged asphalt. As you approach 100% recycled mixes, you tend to lessen the added bitumen quantity and increase the problem with compaction. This results in the need for higher plant temperatures. If the action of recycling agents were completely known and considering other factors such as production, energy and environment the optimization probably lies around 70% recycled and 30% new aggregate. All factors considered and not knowing completely the effects of recycling agents, a 50-50% combination would appear reasonable. One possible solution to the study of recycling agents long term effect on aged asphalt is to precondition the old asphalt prior to incorporation in the hot plant. This could be done by fogging and mixing on a platform or use of a premixing plant. Of course, the cost of this preconditioning would have to be weighed against the ultimate benefit and would result in higher unit costs for recycling.

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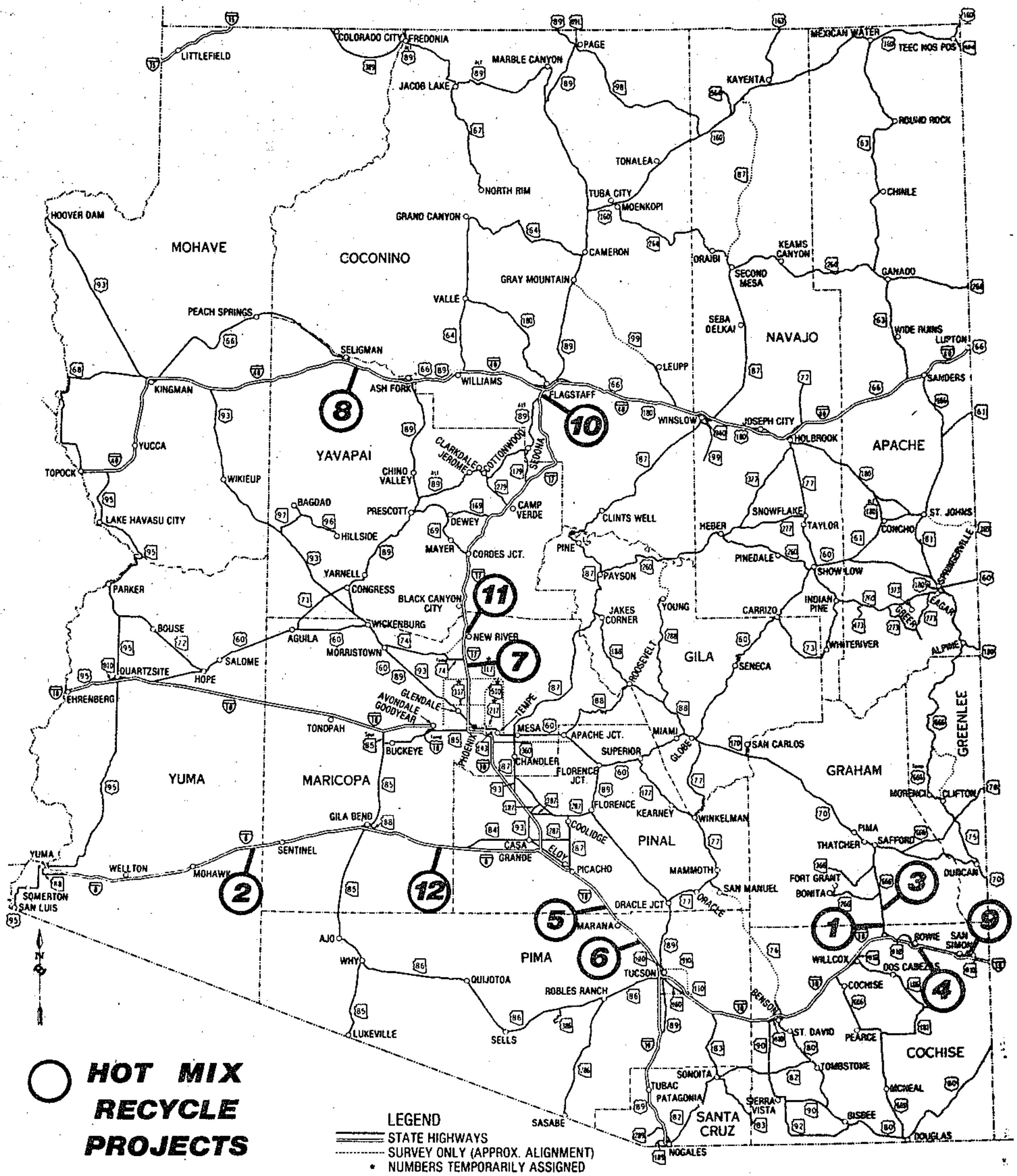
October 1978

RECYCLE PROJECT LOCATIONS



	Project Number	Description	Recycling Types
1.	S 207-904	Bowie Jct. - Safford Start 2/77 Finish 4/77 M.P. 87.9 - 92.9	Hot
2.	I 8-2(76)	Yuma Co. Ln. - East Start 3/78 Finish 5/78 M.P. 79.9 - 95.9	Hot & Surface
3.	F 057-1-901	Cochise Co. Ln. - North Start 8/78 Finish 9/78 M.P. 92.9 - 98.1	Hot
4.	I 10-6(78)	Luzena - Bowie Start 9/78 Finish 12/78 M.P. 356.6 - 362.6	Hot & Surface
5.	I 10-4(66)	Picacho - Marana Start 9/78 Finish 8/79 M.P. 212.8 - 231.8	Hot
6.	I 10-4(68)	Avra Valley - U of A Farms Start 7/79 Finish 9/80 M.P. 244.0 - 255.7	Hot
7.	I 17-1(123)	Bell Road - Skunk Creek Start 3/80 Finish 12/80 M.P. 208.3 - 220.5	Hot & Surface
8.	FRI-I 40-2(86)	Seligman - Pineveta Start 6/80 Finish 4/81 M.P. 123.4 - 139.25	Hot & Surface
9.	I-IR 10-6(84)	San Simon Interstate Freeway Start 2/81 Finish 7/81 (anticip) M.P. 378.3 - 384.1	Hot & Surface
10.	IR-I 17-2(85)	Flagstaff Airport - Flgastaff T.I. Start 4/81 Finish 8/81 (anticip) M.P. 336.8 - 339.7	Hot
11.	FI-I 17-1(136)	Skunk Creek - Table Mesa Start 1/81 Finish 9/81 (anticip) M.P. 220.5 - 236.6	Hot & Surface
12.	I 8-2(79)	Pinal County Line - West Design M.P. 134.6 - 147.6	Hot

RECYCLE AC CHRONOLOGY

Project Number: S207-904

Project Termini: Bowie Jct.-Safford

Length: 5.0 miles

Year Built / Age: 1977/4 years

Traffic (ADT): 1,100

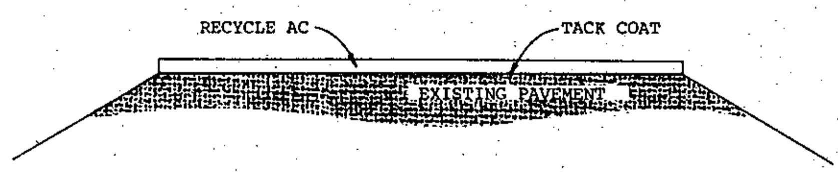
% Commercial Vehicles: 10%

Recycle AC Tonnage: 25,212 tons

Condition Rating: good

Remarks:

TYPICAL SECTION
S207-904



Contractor: D.C. Speer

Bid Price per Ton: **$** 5.50
(Recycle AC)

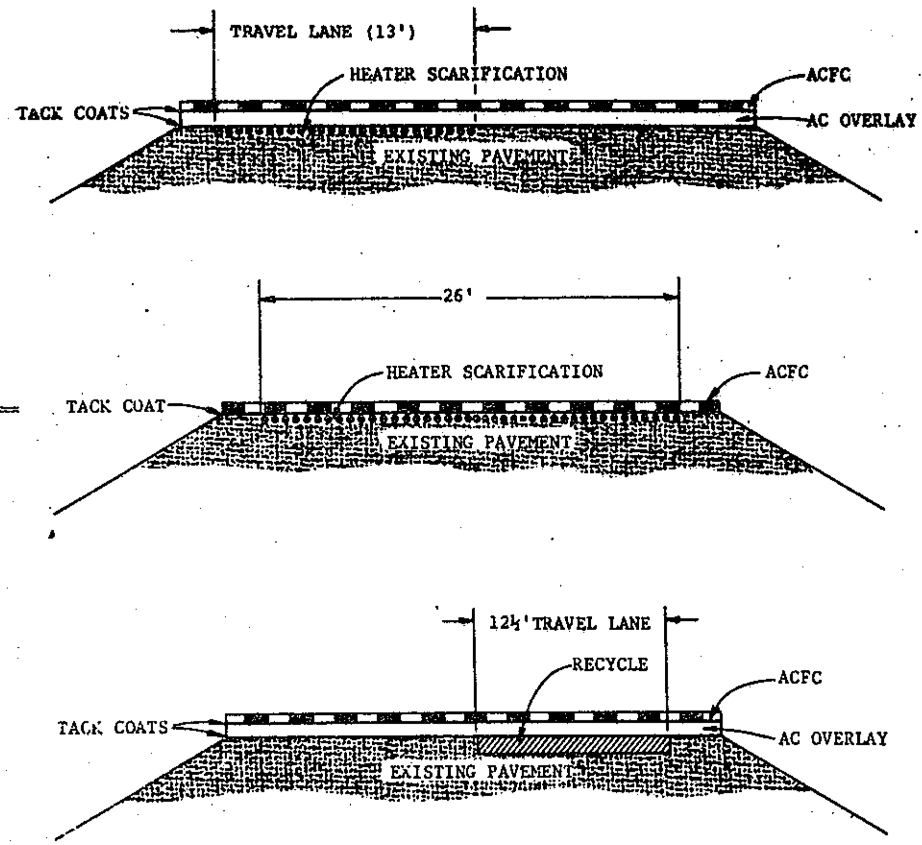
Engineering District #: 3

County: Cochise

RECYCLE AC CHRONOLOGY

TYPICAL SECTION

I8-2(76)C.



Project Number: I8-2 (76)

Project Termini: Yuma County Line-East

Length: 16.0 miles

Year Built / Age: 1978/3 years

Traffic (ADT): 5,200

% Commercial Vehicles: 19%

Recycle AC Tonnage: 10,130 tons

Condition Rating: good

Remarks:

Contractor: Peter Kiewit

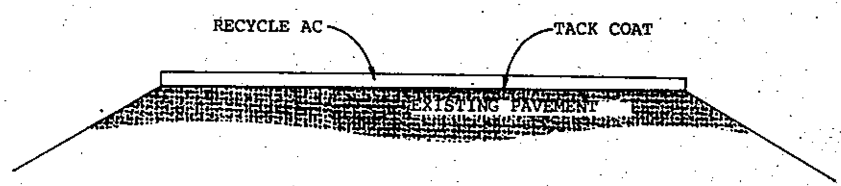
Bid Price per Ton: (Recycle AC) $ 8.50

Engineering District #: 1

County: Maricopa

RECYCLE AC CHRONOLOGY

TYPICAL SECTION
F057-1-901



Project Number: F 057-1-901

Project Termini: Cochise County Line-North

Length: 5.2 miles

Year Built / Age: 1978/3 years

Traffic (ADT): 1,100

% Commercial Vehicles: 10%

Recycle AC Tonnage: 11,007 tons

Condition Rating: good

Remarks:

Contractor: The Tanner Companies

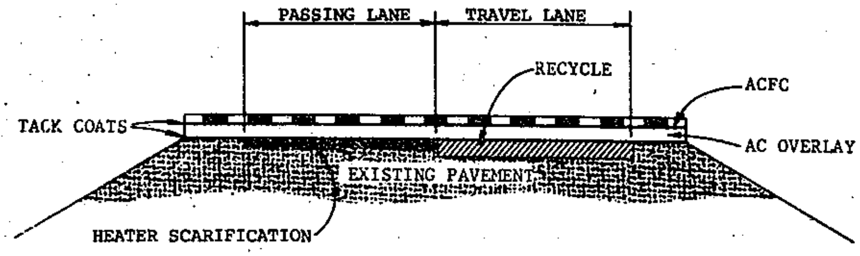
Bid Price per Ton: (Recycle AC) $ 10.00

Engineering District #: 3

County: Graham

RECYCLE AC CHRONOLOGY

TYPICAL SECTION
I10-6(78)



Project Number: I10-6 (78)

Project Termini: Luzena-Bowie

Length: 6.0 miles

Year Built / Age: 1978/3 years

Traffic (ADT): 8,200

% Commercial Vehicles: 29%

Recycle AC Tonnage: 13,721 tons

Condition Rating: good

Remarks:

Contractor: The Tanner Companies

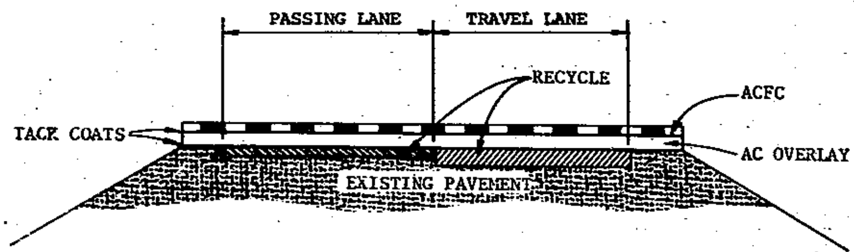
Bid Price per Ton: $ 7.00
(Recycle AC)

Engineering District #: 3

County: Cochise

RECYCLE AC CHRONOLOGY

TYPICAL SECTION
I10-4(66)



Project Number: IR-I10-4 (66)

Project Termini: Picacho-Marana

Length: 19.0 miles

Year Built / Age: 1979/2 years

Traffic (ADT): 14,000

% Commercial Vehicles: 25%

Recycle AC Tonnage: 71,639 tons

Condition Rating: good

Remarks:

Contractor: The Tanner Companies

Bid Price per Ton: $ 6.00
(Recycle AC)

Engineering District #: 2

County: Pinal/Pima

Project Number: IR-I10-4 (68)

Project Termini: Avra Valley-U of A Farms

Length: 11.7

Year Built / Age: 1980/1 year

Traffic (ADT): 35,000

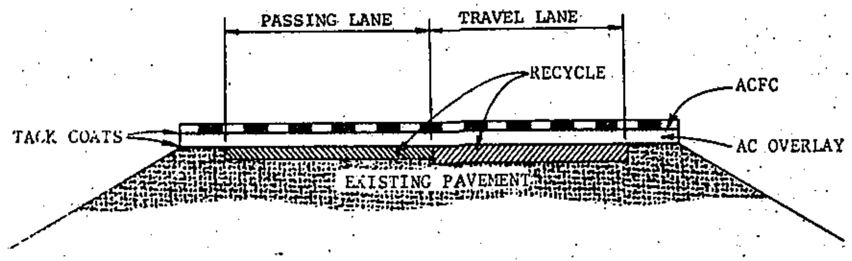
% Commercial Vehicles: 25%

Recycle AC Tonnage: 61,264

Condition Rating: good

Remarks:

TYPICAL SECTION
I10-4(68)



Contractor: Ashton

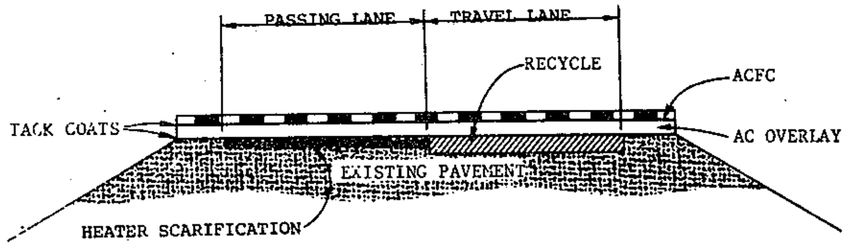
Bid Price per Ton: $ 9.50
(Recycle AC)

Engineering District #: 2

County: Pima

RECYCLE AC CHRONOLOGY

TYPICAL SECTION
I17-1(123)



Project Number: I17-1 (123)

Project Termini: Bell Road-Skunk Creek

Length: 12.2 miles

Year Built / Age: 1980/1 year

Traffic (ADT): 38,000

% Commercial Vehicles: 9%

Recycle AC Tonnage: 13,839 tons

Condition Rating: good

Remarks:

Contractor: Peter Kiewit

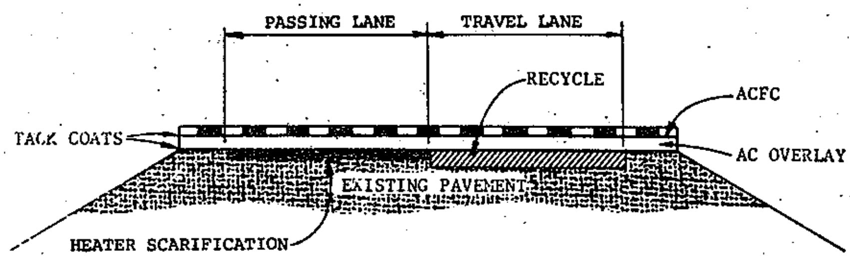
Bid Price per Ton: (Recycle AC) $10.00

Engineering District #: 1

County: Maricopa

RECYCLE AC CHRONOLOGY

TYPICAL SECTION
FRI-I40-2(86)



Project Number: FRI-I40-2 (86)

Project Termini: Seligman-Pineveta

Length: 15.85 miles

Year Built / Age: 1981/4 months

Traffic (ADT): 5,200

% Commercial Vehicles: 21%

Recycle AC Tonnage: 89,238

Condition Rating: good

Remarks:

Contractor: The Tanner Companies

Bid Price per Ton: (Recycle AC) $7.00

Engineering District #: 6

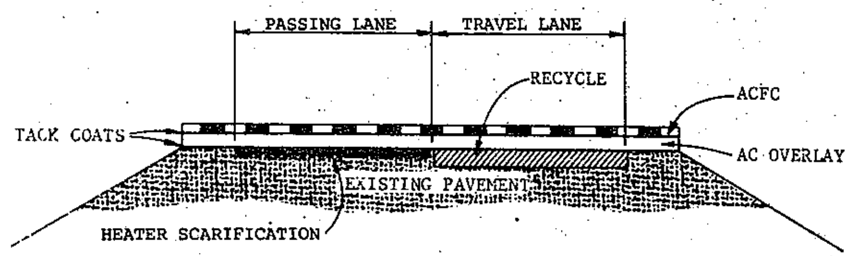
County: Yavapai

RECYCLE AC CHRONOLOGY

Project Number: I-IR 10-6 (84)

Project Termini: San Simon Interstate Freeway

TYPICAL SECTION
I-IR10-6(84)



Length: 5.8 miles

Year Built / Age: 1981/1 month

Traffic (ADT): 8,500

% Commercial Vehicles: 29%

Recycle AC Tonnage: 45,348

Condition Rating: very good

Remarks:

Contractor: Nesbitt

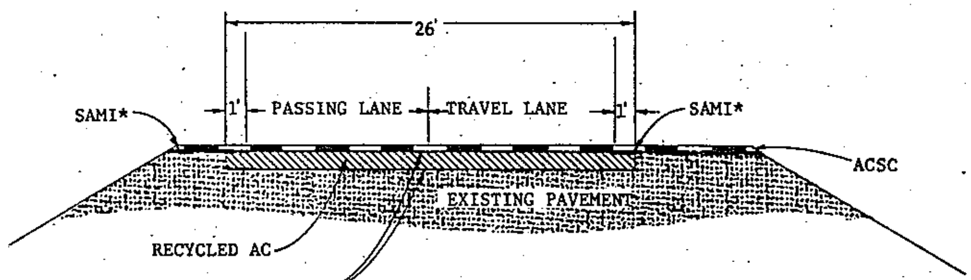
Bid Price per Ton: (Recycle AC) $ 5.26

Engineering District #: 3

County: Cochise

RECYCLE AC CHRONOLOGY

TYPICAL SECTION
IR-I17-2(85)



*TACK COATS PRIOR & AFTER PLACEMENT OF SAMI

Project Number: IR-I17-2 (85)

Project Termini: Flagstaff Airport-Flagstaff T.I.

Length: 2.9 miles

Year Built / Age: 1981/1 month

Traffic (ADT): 11,000

% Commercial Vehicles: 14%

Recycle AC Tonnage: 24,320

Condition Rating: good

Remarks:

Contractor: W.R. Skousen

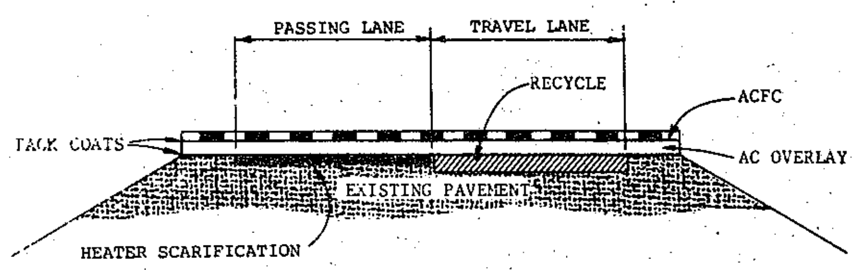
Bid Price per Ton: (Recycle AC) $ 8.60

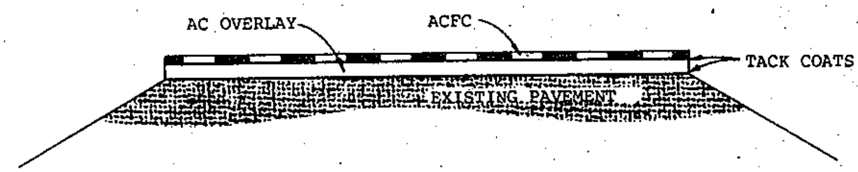
Engineering District #: 5

County: Coconino

RECYCLE AC CHRONOLOGY

TYPICAL SECTION
FI-I17-1(136)





Project Number: FI-I17-1 (136)

Project Termini: Skunk Creek-Table Mesa

Length: 16.1

Year Built / Age: 1981/1 month

Traffic (ADT): 13,000

% Commercial Vehicles: 10%

Recycle AC Tonnage: 41,395

Condition Rating: good

Remarks:

Contractor: Ashton

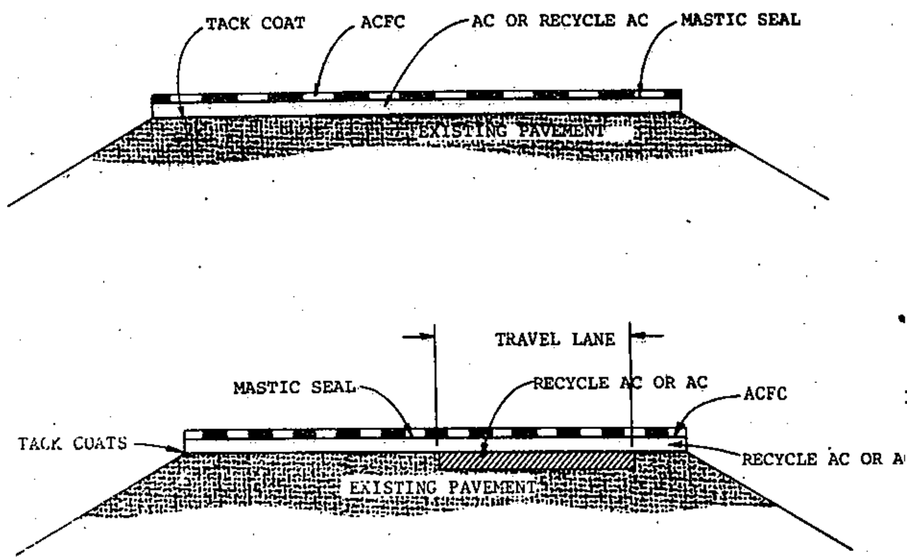
Bid Price per Ton: $8.00
(Recycle AC)

Engineering District #: 1

County: Maricopa

RECYCLE AC CHRONOLOGY

TYPICAL SECTIONS
IR8-2(79)



Project Number: I8-2 (79)

Project Termini: Pinal County Line-West

Length: 13.0 miles

Year Built / Age: project underway

Traffic (ADT): 5,000

% Commercial Vehicles: 30%

Recycle AC Tonnage: no work performed as of 7-25-81

Condition Rating:

Remarks:

Contractor: Ashton

Bid Price per Ton: (Recycle AC) $ no work performed as of 7-25-81

Engineering District #: 1

County: Maricopa

PRESENTATION FOR

ASPHALT CONCRETE RECYCLING SEMINAR

SPONSORED BY FHWA & CALTRANS

SEPTEMBER 15, 16, 17, 18, 1981

ON-GRADE COLD RECYCLING PROJECT

FOR RUSSELL AVENUE

BY

LES JORGENSEN, P. E.

PROJECT DEVELOPMENT ENGINEER

FRESNO COUNTY DEPARTMENT OF PUBLIC WORKS

PROJECT HISTORY

Russell Avenue between Shaw and Herndon Avenues, a length of 2 miles, was constructed in 1968. The structural section was .17' Road Mixed Aggregate Surfacing (RMAS) over 1.00' Lime Treated Base (LTB). A 0.12' Asphalt Concrete overlay was added in 1971.

Due to a rapid increase in traffic loads caused by a new commercial aggregate plant, intensified farming of truck crops such as tomatos and cantalopes, and a deterioration of the lime treated base, the reconstruction of Russell Avenue was undertaken as an emergency project in 1977.

We recognize the investment in the pavement on this project, approximately 5,000 tons of surfacing at a cost of about $55,000 and decided we must salvage and recycle this material. A structural section using the existing pavement as an Asphalt Treated Base, in lieu of constructing a Class 2 Aggretate Base, was selected.

PROJECT DESIGN

An analysis of the existing pavement is a very important step in the design of a recycled pavement. The ultimate success is dependent upon the proper amount and type of recycling agent used. Since we are going to make maximum use of the existing asphalt in the old pavement and add the least amount of new asphaltic binder material, it is necessary to evaluate both the chemical components of the asphalt and the physical performance of the completed mix.

The asphalt in the existing pavement was analyzed by personnel in the Golden Bear Division of Witco Chemical Corp. Their test data resulted in the recommendation of using 2% Cyclogen HE to satisfy the rejuvination requirements of the aged asphalt.

The physical properties of the recycled pavement mixture were analyzed by the County of Fresno Materials and Research Lab. Based on asphalt demand, stabilometer valves and cohesion tests, the addition of 2.5% Cyclogen HE was recommended.

The structural section for this project is based on a conservative approach for the value of the recycled pavement. We decided to view this recycled pavement as an asphalt treated base for structural design purposes rather than a road mixed asphalt surfacing.

The structural section, based on a 10 year T.I. of 8.4 and a native soil R-Valve of 7, is as follows:

A.C. (Future)	0.10'
A.C.	0.20'
A.T.B. (G.E. = 1.2)	0.25'
I.B. (70-R-Valve)	1.70'

PROJECT CONSTRUCTION

The construction sequence for this project consisted of pulverizing the existing pavement, hauling it to a stockpile site adjacent to the job, constructing the subgrade and subbase, hauling the pulverized pavement back to grade, mixing this material with Cyclogen HE, and then placing, shaping and compacting this mixture as the asphalt treated base. The following slides will show the above described process:

(SLIDE PRESENTATION)

A brief description of the construction process as shown by the slides is as follows:

First steps in the rebuilding project involved pulverizing the existing pavement with crawler dozers with ripper teeth and grid rollers and pull-mixers and then picking up the material with self-propelled elevating scrapers and transporting it to a stockpile area adjacent to the project.

At this point normal construction activities began by grading, shaping and importing the sub-base material. Upon completion of this phase, the stockpiled pulverized pavement was returned to grade. This surfacing was hauled back in bottom dump trucks to form windrows of material which could be further pulverized, sized and prepared for mixing with the reclaiming agent.

The actual field procedure for mixing the reclaiming agent with the pulverized pavement was as follows: The salvaged pavement, which was pulverized so that 95 percent passed through a one inch sieve, was then separated into three uniform windrows so that the motor graders and pulvi-mixers could readily handle the material. The plan was to mix one windrow with the reclaiming agent each day.

The process used for the first two windrows was to flatten them out with a grader to a width of 8 feet, apply the reclaiming agent at a predetermined rate through an asphalt distributor, and then windrow the material again with the grader and mix the entire windrow with a pulvi-mixer. This process was repeated two more times for each windrow and, after all the reclaiming agent was added, mixing was continued for the remainder of the day.

Material in the third windrow was flattened out to the width of 16 feet and treated with the reclaiming agent, then mixed with graders and pulvi-mixers as described above. This method was the idea of our road foreman; it resulted in better agent-aggregate coating since more aggregate material came in direct contact with the agent because of the wider application from the distributor truck.

After the reclaiming agent had been applied and all mixing completed, the material was spread and compacted across the designed width of 32 feet, using graders, grid roller and rubber tired rollers. The mix was extremely stable, even though a completely homogeneous mixture could not be obtained under our field conditions.

Since the surface appeared to be quite porous and a little on the dry side, it was decided to treat it with Reclamite rejuvenating agent, undiluted, at the rate of 0.08 gallon per square yard. The Reclamite penetrated immediately with no residue remaining on the surface so the normal sanding, usually recommended, was unnecessary. After this treatment, the surface was opened to heavy agricultural traffic for two weeks prior to the surfacing with asphalt concrete under contract.

POST CONSTRUCTION REVIEW

Pavement cores were obtained in January, 1979, along with a detailed visual inspection. The pavement is in excellent condition and the Recycled ATB appears almost as good as the A.C. pavement. There appears to be no deterioration of this base and it appears that the cohesion that we hoped for has been achieved.

In March of 1979, tests were performed on the extracted asphalt taken from samples of the recycled pavement used in the asphalt treated base layer which supported the effectiveness of the rejuvenating agent. The results are as follows:

DATA	ORIGINAL PAVEMENT	RECYCLED PAVEMENT
Penetration @ 77° F	25	92
Viscosity @ 140° F	19,600 p	1,120 p

In August of 1981 additional pavement cores were obtained. The coring process required the use of more water than usual and some damage was caused to the ATB layer. The appearance of the ATB layer of the core was slightly dryer than the A.C. pavement. However the ATB was still cohesive and stable.

The pavement on this project has been monitored over the past four years by means of a road rater to obtain deflection data. The following is a summary of the results:

DATE	Δ RANGE	80% Δ	TOLERABLE Δ*
1978	.026 - .044	.038	.026
1979	.029 - .046	.041	.026
1981	.027 - .042	.038	.026

* Using a T.I. of 8.0 & 0.20' A.C.

Pavement distress has been limited to minor depressions in the wheel tracks which we believe are caused by the intensive use of 5 and 6 axle trucks hauling farm crops during the summer months.

COST ANALYSIS and TEST DATA - See attachments A and B.

ATTACHMENT A

COST ANALYSIS TO RECYCLE PAVEMENT FOR AN ASPHALT TREATED BASE

RUSSELL AVENUE, SHAW TO HERNDON IN THE COUNTY OF FRESNO

PHASE I - Rip, Pulverize, and Stockpile
April 18 - 28, 1977 (9 days)

		Hours	Amount
2	Motor Graders (Wabco 660B)	84	$1,237
1	Crawler-Dozer w/Ripper/Compactor (Cat D-7)	45	907
1	Crawler-Dozer W/Ripper (Cat D-6)	42	670
1	Grid Roller (Hyster Towed by D-6)	42	10
2	Motor Scraper (JD 760)	37	628
1	Heavy Wheel Tractor (JD 4020)	20	163
1	Pull Mixer (REX D47)	11	189
1	Water Truck (White Star)	53	540
-	Other Miscellaneous Equipment	--	135
			$4,479
	Man Hours @ $9/Hr. Average	320	2,880
	Supervision and Overhead		1,584
			$8,943

PHASE II - Replace, Pulverize, and Windrow
July 5 - 8, 1977 (4 days)

		Hours	Amount
2	Frontend Loaders (Hough H50 and H65)	32	512
4	Bottom Dump Trucks (DIA REO - 20 c.y.)	78	1,271
2	Motor Graders (Wabco 660B)	47	678
1	Heavy Wheel Tractor (JD 4020)	7	45
1	Pull Mixer (REX D47)	7	120
1	Water Truck (DIA REO)	10	85
-	Other Miscellaneous Equipment	--	85
			$2,796
	Man Hours @ $9/Hr. Average	190	1,710
	Supervision and Overhead		1,013
			$5,519

PHASE III - Mix w/Cyclogen HE, Place, Compact, and Finish
July 8 - 15, 1977 (7 days)

		Hours	Amount
3	Motor Graders (Wabco 660B and Huber F1500)	136	$ 2,170
2	Heavy Wheel Tractors (JD 4020 and 4320)	74	536
2	Pull Mixers (REX D47)	72	1,235
1	Water Truck (DIA-REO)	34	289
-	Other Miscellaneous Equipment	---	120
			$ 4,350
	Material (Cyclogen HE @ 2.5%±)		15,133
	Finish Seal (Reclamite @ 0.08 g.s.y.)		1,187
	Man Hours @ $9/Hr. Average	300	2,700
	Supervision and Overhead		1,510
			$24,880

SUMMARY

PHASE I	Rip, Pulverize, and Stockpile	$ 8,943
PHASE II	Replace, Pulverize, Windrow	5,519
PHASE III	Mix w/Cyclogen HE, Place, Compact, and Finish	24,880
	TOTAL	$39,342

NOTE: Class 2 A.B. Cost Estimate was $47,200.

ATTACHMENT B

TEST DATA ON PAVEMENT TO BE RECYCLED

RUSSELL AVENUE, SHAW TO HERNDON

PRELIMINARY TESTS SUMMARY

A. Existing Pavement, Pulverized and Untreated

Location	% Asph.	Stab	R-Value	Grading, % Passing
Stockpile	3.9 to 4.4	-	66 to 76	1½" - 100% 1" - 95 3/4" - 89 1/2" - 77 3/8" - 69 #4 - 49

B. Pulverized Pavement, Treated as Shown

Product Used	Stability	Cohesion
W/1% Reclamite	47	168
W/ " & 1% SS1-H	40	334
W/ " & 2% SS1-H	25	474
W/ " & 1% MC-800	41	315
W/ " & 2% MC-800	20	410
W/2% Cyclogen HE	46	351
W/3% Cyclogen HE	40	522

Based on the above data, 2.5% Cyclogen HE selected.

CONSTRUCTION CONTROL TESTS SUMMARY

A. Date Sampled: July 13, 1977 (1st Spread)

Location	% Asph.	Stab	Cohesion
Sta. 117	5.7	46	220
Sta. 135	5.1	46	270
Sta. 153	5.3	47	330
Sta. 180	5.6	50	180
Sta. 200	5.6	46	190

B. Date Sampled: July 15, 1977 (Combination of 3 Spreads)

Location	% Asph.*	Stab	Cohesion
Sta. 117	-	36	590
Sta. 135	-	44	400
Sta. 170	-	40	220
Sta. 199	-	43	170

*1% additional Cyclogen HE added to samples.

Based on above data and funding limitations, 0.5% Cyclogen HE was added to increase density and cohesion.

SURFACE RECYCLING

EVALUATION - DESIGN - EQUIPMENT - CONSTRUCTION

JOSEPH L. VICELJA

MATERIALS ENGINEER

LOS ANGELES COUNTY ROAD DEPARTMENT

SEPTEMBER 1981

Surface recycling is concerned with the maintenance and restoration of the surface of an existing roadway, airport, etc. When the term surface recycling is used, it is referring to a process which involves re-working the top 3/4 to 1 inch of the existing pavement in place and is called heater-scarification.

The process of removing the surface of an asphalt concrete pavement may involve using heat to soften and break up the surface or it may be broken up by powerful machines which do not use any heat.

Depending on the equipment and procedure used, this could be done as a one phase or multi-phased construction procedure. The processes using heat is heater-planing while the cold processes are referred to as cold-milling and cold-planing, Figure 1.

What is the first thing that must be done to determine if a project is a candidate for surface recycling? Make an evaluation of the pavement deficiencies and catagorize the types of distress.

Cracking	fatigue (load associated)	
	reflection	
	oxidation (shrinkage)	
Pavement Roughness	humps	
	shoving	
	rutting	
Low Coefficient of Friction		polished aggr.
		bleeding
Raveling		
Inadequate Structural Capacity		

Some engineering considerations or design parameters which should be investigated on surface recycling projects are:

Mix Design

Structural Properties

Construction Uniformity

Now that the analysis of the previous data indicates that surface recycling is appropriate, a detailed testing program should be employed to determine the best way to correct the situation. This testing program should include:

In-place non-destructive testing of the roadway.

Coring of the pavement

Extract & recover the asphalt & aggregate

Determine aggregate properties

Determine asphalt properties

Determine properties of recycling agent

Blend recycling agent with recovered asphalt and retest

Results of this testing program will indicate if the pavement can be salvaged in place by heater-scarification, or if it must be removed by milling or planing. Use standard design procedures to determine the thickness of overlay required. All the preparatory work to constructing the project has been completed except writing the specifications. They are not unlike other construction specifications, they should be complete and cover such items as:

What you want done

How it may be accomplished

Type of acceptable equipment

Quality control procedures

Time or climatic requirements

Amount and Type of recycling agent

Temperature controls

Once construction has begun, a good inspection and quality control program must be maintained to insure the desired results. As a minimum it should include:

Surface preparation

Depth control

Traffic control

Temperature control

Application rate of recycling agent

There are two primary procedures; milling and planing used for the removal of material or truing up of a surface. It is important to know what each is, how they differ, as well as, how they are used.

Milling - refers to the removal of asphalt concrete pavement by means of a rotating drum with special cutting bits. These machines are made in various sizes and widths. Some are capable of maintaining quite accurate grade control by means of electronic controls. The depth of cuts vary from 0" to 5" and can either be set for a uniform depth or as a tapered section. This is an efficient and effective way to remove pavement to a specified section or grade. The cost is variable and is greatly influenced by the amount of work to be done. This is a cold operation and no heating is required. Some of the equipment is capable of self loading the millings (removed asphalt concrete) into trucks for removal, while others require self propelled loaders or street sweepers to pickup the millings. The cleaned surface is generally left in such a condition that it may safely be used by traffic. However, loose pieces of aggregate can often be dislodged under traffic and advisory signs, "Loose Gravel" should be appropriately placed.

Planing - refers to removing the surface of an asphalt concrete pavement by scraping it off with a steel blade, generally a motor grader. The type of pavement and climatic conditions will dictate if this process can be done cold or if heat must be added to the pavement. Besides being slower then milling, the depth of removal and grade control can not be maintained as well. The cost of cold planing is the least of any of the operations being described. Hot planing is more costly, but less then cold milling. The planed material can be removed by loaders or street sweepers. The planing operation, unlike the milling, generally can not cut through a piece of rock and must dislodge it if it is to be removed, resulting in a rough surface. The planed surface can be used by traffic, however, caution signs indicating "Rough Road" and "Loose Gravel" should be properly placed to advise the motorist of the roadway conditions.

Surface Recycling Procedure

Heater-scarification is the only true surface recycling procedure presently available. In order to accomplish this operation, controlled heating is necessary to soften the pavement for scarifying without damaging the asphalt. Scarifying refers to the remixing of the top 3/4 to 1 inch of asphalt concrete pavement by tines. This heat is provided by self propelled heaters or ovens using liquid petroleum gas or diesel oil as their fuel. They may be of the open flame type or indirect radiant heat type. Infrared heaters are being investigated and evaluated by some contractors after their successful use in Germany. Generally two heaters are required to properly soften the pavement, with the scarifying tines employed only behind the last heater. The tines are spring loaded and generally are hydraulically mounted so that a downward force can be applied to aid in getting the proper penetration. After the pavement is scarified it must be screeded, rolled and if necessary, a recycling agent applied before it may be opened to traffic. Some pieces of aggregate may be dislodged by traffic and posting of "Loose Gravel" signs would be appropriate.

With these definitions it is much easier to understand what is meant when terms like cold-milling, heater-scarifying etc. are used.

Pavement Evaluation

A thorough study of the pavement is needed to establish the most economical approach to rehabilitating the roadway. This study should include a review of the construction, as well as the maintenance history of the various segments. Evaluate the structural properties of the various materials making up the structural section, not only at the time of construction but also in their present state. This, combined with the distress analysis of the roadway, non-destructive in-place pavement testing and laboratory analysis of pavement cores, can provide you with the necessary data to make the best engineering decisions.

Pavements exhibit many forms of distress. Cracking can be either load associated (fatigue) or non-load associated (reflection or oxidiation).

Fatigue cracking is due to flexural fatigue and often is referred to as alligator cracking, Figure 2. This type of cracking can often be repaired by the heater-scarification process, but a review of the non-destructive testing data will determine if removal by cold-milling or heater-planing may be required. Generally an overlay is required to overcome the structural deficiency.

Reflection cracking is the transmission of a crack to the surface from an underlaying material, Figure 3. This crack could be from PCC pavement, asphalt concrete pavement, cement treated base, etc. and usually is not load associated. These cracking patterns can be effectively broken up by the heater-scarification process, thereby, delaying their reflecting up to the new surface placed on the roadway.

Oxidation or shrinkage cracking is the result of the volatiles in the asphalt evaporating out over a long period of time with the pavement becoming hard and brittle. An oxidized pavement usually appears gray, dried out and dull. Oxidation occurs most rapidly at the surface which is in contact with the elements. As the pavement expands and contracts, due to temperature variation, stresses build up within the asphalt concrete which may exceed the elastic properties of the asphalt, resulting in cracking. These cracking patterns are generally more spread out then flexural cracks and often form large blocks, Figure 4. Heating and scarifying the pavement will break up the cracking pattern but a recycling agent must be added to restore the asphalt to its original condition and elasticity. How this is determined and done will be discussed later.

Pavement roughness, due to humps, shoving, or rutting, is generally an indication of an unstable mix and the cause needs to be established through laboratory testing. The material usually should be removed by milling or planing and replaced with a properly designed asphalt concrete.

Pavement surfaces may have low skid resistance due to the polishing of the aggregate or to a bleeding or flushed condition. During the heater-scarification process the tines will tumble the aggregate and expose other non-polished surfaces, thereby increasing the skid resistance. To correct a flushed or bleeding condition, the material can be removed by milling or planing or a sprinkle treatment can be used. Often times the planing or sprinkle treatment requires more than one application. The sprinkle treatment consists of spreading 1/4" up to 1/2" chips (one size only) on the roadway, depending on the condition of the surface, heating the chips and the pavement with a heater (no scarification) and rolling them into the flushed surface. The excess asphalt should hold the aggregate in place. The greater the amount of bleeding, the larger the chip size used. Surface raveling can often be corrected without recycling. However, on heavily traveled highways, heater-scarification with the addition of a recycling agent may be the most economical solution.

If the pavement distress is due to inadequate structural capacity, surface recycling will not correct the problem, but hot or cold recycling can be used to help increase the structural thickness needed.

Testing Program

Analysis of the pavement history and distress may permit the engineer to accurately determine the type or cause of failure, however, he needs additional data to design the recycled mix and overlay requirements. By use of a Road Rater or Benkleman beam, data can be obtained to evaluate the structural integrity of the existing pavement, from which the required overlay may be designed.

Often, several recycling procedures may be used on the same project. To evaluate the asphalt concrete mix and determine what deficiencies, if any, need be corrected, cores should be obtained from the pavement. The number and frequency of cores will be greatly influenced by the information obtained during the pavement evaluation. If the roadway was constructed all at the same time, then 3-5 cores should be sufficient to determine the properties and consistency of the pavement. If the proposed project has been widened or constructed under different contracts, then these areas also need to be investigated and the program expanded.

After determining their specific gravity, the cores should be heated in an oven sufficiently to permit the removal of the top 3/4 to 1 inch for analysis. The mixture should be extracted and the asphalt and aggregate recovered. Determine the gradation of the aggregate, and in the case where the pavement has low skid numbers due to polished aggregate, evalaute its polish value per ASTM D 3319. The asphalt should be recoverd by the Abson procedure and the viscosity @ 140°F and penetration at 77°F determined. With four inch diameter cores you may not have sufficient asphalt to perform the penetration tests, unless two cores are taken side by side and combined.

The viscosity data obtained from the recovered asphalt should be plotted on a Viscosity Blending Chart, Figure 5, to aid in selecting the amount and type of recycling agent to use. There are five grades of recycling agents, properties of which are shown on Table 1. This table is for recycling agents in the non-emulsified form, used for hot recycling and some heater-scarification projects. Table 2 is suggested limits for emulsified recycling agents used on heater-scarification and cold recycling projects. The rejuvenating properties and viscosity of each grade is the same, only the percent of residue varies. Laboratory testing of the blend of recovered asphalt and non-emulsified recycling agents or emulsified recycling agents from which the water has been removed, is needed to determine the resultant properties of the rejuvenated asphalt. After selecting the grade and amount of recycling agent to use from the Viscosity Blending Chart, prepare laboratory samples of this blend, as well as, greater and lesser quantities and test their viscosity. This will confirm the analysis and also provide a guide as to the latitude in application rate to meet the desirable viscosity range of the rejuvenated asphalt. Note, that when using an emulsified recycling agent, the application rate should be increased to compensate for the water in the product. See Appendix A.

If the asphalt in the pavement to be recycled has not increased in viscosity greatly from the time of placement, it could be that a low viscosity paving asphalt, ie. AR 1000 or AR 2000, would be appropriate to use as the recycling agent.

Standard design procedures should be used to determine the thickness of overlay required. The mix can be produced from either recycled asphalt pavement or new materials and should meet the standard requirements for an asphalt concrete.

Equipment

There is a wide variety of equipment available to perform surface removal. Milling equipment probably is the most variable, Figure 6. Equipment is manufactured in varying cutting widths from 1 foot to 12 feet. The larger machines are capable of making cuts up to 5 inches in one pass, while the smaller machines are limited to milling only a few inches per pass. The larger equipment is supported on tracks or solid tired wheels. A modified motor grader frame is used to support the milling machine of medium sized millers 60-78 inch cutting width. Water is sprayed from an onboard tank to reduce the dust and cool the cutters and pavement. Automated grade control equipment on some milling machines permit them to profile a highway to a specified grade. The one foot wide miller is very maneuverable and ideal for milling around manholes and drainage structures. The size of the millings are dependent on the depth of cut, number and condition of the cutting bits, and to a lesser degree if the machine is up cutting or down cutting (referring to the rotation of the cutting drum). They vary in size from 1/2 to 2 inches or larger.

Costs for milling the pavement and loading the millings range from $0.40 to $1.20/sq.yd. per 1 inch removal. Fuel consumption for removing one inch is in the order of 600 to 2500 BTU/sq.yd. Production rates vary considerably depending on equipment used, type of pavement, depth of removal and traffic. Production rates could be as high as 300 tons/hour.

Most heaters are contractor manufactured or modified. Their length varies from 14-30 feet with widths in the 12-14 foot range. The heaters are propelled by semi-tractors with special gearing to permit them to move uniformly at speeds of 5-50 feet/minute. The units are completely self contained and carry their own fuel, LPG or diesel fuel. The fuel is burned inside the heating chamber usually as an open flame, however, some units are designed as radiant heaters and the pavement is not subject to the open flame. A West Germany contractor has developed a gas fired infra-heater unit which is capable of softening the pavement to depths of 3 inches. This equipment is expected to be marketed in the United States in the near future. The heaters will generate more than 8,000,000 BTU's/hour. There is a great deal of individuality among this equipment because of contractor ingenuity, Figure 7. All heaters can be raised and lowered in the vertical direction and many can be displaced laterally by hydraulic rams or by rear wheel steering. Other features found on various heaters are; the burners may be turned on or off individually or as groups of 3 or 4, water tanks and pumps for spraying trees and shrubs as the heater passes, heat vent deflectors to protect trees and plants and screeds or leveling devices which vary from heavy steel blades to chain link fencing. For scarification the heater should be equipped with at least 2 rows of spring loaded tines, often they are hydraulically controlled thereby permitting a greater downward force then with gravity type scarifies. Some are designed to operate at varying widths by turning off some burners and raising the complimentary scarifiers while others only permit the tines to operate for the full width of the heater.

To heat and scarify a pavement to a 3/4 inch depth costs from $0.25 to $0.70 per sq.yd. Fuel consumption is in the order of 8000 to 15,000 BTU/sq.yd. for 3/4 inch scarification depth. Production rates vary from 1000 to 2000 sq.yd./hour and are influenced by equipment used, type of pavement and ambient temperatures.

Heater-planing uses the same heater as described above but instead of using a scarifier, a motor grader is used to plane off the pavement. The range of costs and fuel consumption are about the same as above. The production rate is influenced by the factors enumerated for heater-scarification, plus the depth factor which often is quite variable.

Cold-planing is generally done with a motor grader having a hardened steel blade. This operation is generally done in the summer when the pavement temperature would be sufficiently high to permit planing. The cost and fuel consumption would be commensurate with normal motor grader operations. Production is almost totally determined by pavement type and temperature.

Geometric Design

The design of the recycled pavement and the overlay design has already been discussed. What I wish to point out here are the design considerations as they apply to the width and depth for surface removal and recycling.

Lets consider milling first. Suppose the wheel paths show sufficient distress that the existing pavement must be removed, when determining the width to be removed consider the availability of equipment. Do not just ask for 14 feet removal because that is the overall width of your pavement, try to match it to the width of distress and equipment.

Most large milling equipment have 10 or 12 foot cutting drums. To remove the additional two or four feet to meet the 14 foot width may be quite expensive and unnecessary. If you are making wedge cuts adjacent to curb and gutters or header cuts across the pavement where the new overlay joins the old pavement the width and depth should be established to provide smooth joins and transitions. The depth of cut should be twice the maximum size aggregate to be used in the overlay. With a 1/2 inch mix, generally 1 inch cuts will provide good joints. The length of the transition for header cuts should be 10-20 feet. This length should be sufficient to permit the paving machine to attain the full depth of the overlay before it reaches the end of the transition.

Wedge cuts, made to join existing gutters, should be of such width, 5-6 feet, that the beginning of taper will occur under the middle of the paving machines. If the width of cut is not considered, the paving problems that can be encountered are pulling of the mix and insufficient thickness, to prevent breaking the rock as it passes under the screed.

Whenever heating a pavement, try to avoid heating more area then is necessary. Beside the economic considerations, the heat changes the physical characteristics of the asphalt near the heated surface. When heater-planing, turn off the burners in the area not to be planed.

Heater-scarification requires more thought for the design then one might think. It is important that once the scarification process is completed that it not be reheated and rescarified. The designer must recognize this and call out the width of the work to be commensurate with the full width of the heater. Figure 8 illustrates two examples where the heater-scarification is centered about the center line of the roadway, while in the second case with the raised median, the recycling begins adjacent to the gutter edge and covers both traveled lanes and part of the parking lane. Generally parking lanes do not need recycling due to the lesser traffic, also because of the oil drippings, undesirable smoke may be created during the heating process.

Specifications

The specifications writer should visit the various types of surface removal and recycling projects and become familiar with the construction operations, equipment and areas where controls are critical in order to prepare meaningful specifications. After determining what bid items you wish to call for, it is necessary to tell the Contractor what you want done. Specify the minimum depth you want processed along with a reasonable tolerance, if appropriate. Permit the contractor as much latitude as possible to use his ingenuity in selecting the equipment to do the work, but do not hesitate to specify a certain piece of equipment if necessary. Spell out how the project will be controlled and what the contractor can expect if the specifications are not adhered to. For example, the depth specified to be removed by cold-milling is based on the mix design, but you do not want more removed then needed, as additional asphalt concrete will be required to bring the new pavement up to grade. Often this can be controlled by specifying a deduction equivalent to the cost of the additional asphalt concrete. Also, do not try to hide things from the contractor because it will usually end up costing more because of the uncertainty. If using a recycling agent do not lump it in with the heaterscarification item while specifying an application rate between 0.15 0.25 gal./sq.yd. Set it up as a separate item and the contractor will not have to cover the eventuality and cost that the

Engineer may ask for the recycling agent to be applied at the upper end of the range specified. Lump sum contracts are easier to estimate and administer, but this convience can often cost more money. Appendix B and C are sampled specifications for Cold-Milling and Heater-Scarification.

Quality Control

A construction control testing program combined with adequate inspection by trained personnel is needed to assure that the final result will meet your design parameters. The milling and planing operations generally do not require testing unless the removed material is to be recycled back into another product ie. hot or cold recycled asphalt concrete or crushed miscellaneous base.

The heater-scarification operation requires a good quality control testing program to furnish the construction inspector and contractor needed information such as, depth of scarification, surface and internal temperatures and application rate of the recycling agent. The Arizona Highway Department developed a construction control test for depth of scarification, often referred to as the "Nine Pound Test". The nine pounds refers to the weight of one square foot of pavement 3/4 inch thick, based on 144 pounds per cubic foot. Data obtained from the previously tested cores will indicate if the nine pound value should be adjusted. The test can be performed in the field by the inspector in 2-3 minutes, Figure 9. A ring of known diameter, generally a frame from a 12" diameter sieve with the screen removed, is placed on the scarified pavement and all the loose material is removed from inside it and weighed. Determine the weight of removed material per square foot and compare it to the nine pound figure. Values less then nine pounds require an adjustment in the operation to attain the 3/4 inch depth. The internal temperature of the scarified material usually is checked while performing the 'Nine Pound Test" to assure adequate temperature for compaction.

Surface temperatures can get quite high and should be maintained as low as possible to reduce damage to the asphalt, such as rapid oxidation or coking. There is some tolerance in the amount of recycling agent needed to rejuvenate the scarified material. However, too much recycling agent, is as bad as too little and may over soften the material and lead to bleeding problems.

When recycling any material, it can not be overstressed, that considerable testing is required before, during and after the construction of the project. The after testing is necessary to confirm the design parameters and assure that the pavement is performing as intended. A thorough knowledge of the material being worked with is needed to make sound engineering decisions.

Case History - Heater-Scarification

In September of 1980, Western Avenue from Imperial Highway to El Segundo Boulevard was surface recycled. This case history will present information on the pertinent events in the life of this pavement since its construction in 1961 to present. The typical structural section, Firgure 10, also shows the PCC pavement constructed in the 30's and overlaid in 1961. The surface course of asphalt concrete was a 1/2 inch mix with 120/150 (AR 2000) paving asphalt. No seals or surface treatments were applied to this pavement. Some cracking was observed in the right wheel path of the number two lane in addition to reflection cracking over the PCC pavement.

A crack survey was made when the Road Rater deflection data and cores were obtained. Laboratory analysis indicated that by applying 0.17 gal/sq.yd. of RAE5S the viscosity of 109,000 poises could be reduced to an acceptable level. Based on deflection and traffic data, a one inch overlay should be adequate for 10 years.

Many construction problems had to be overcome. Being a new construction procedure, only a general specification was written and the inspector had to learn the significance the different operations would have on the final product. It is important to keep the heaters close to each other in order to get proper depth of scarification, also require the paving screed to be heated and kept close to the heaters. This was all brought out vividly as the material cooled to the point that it would not pass under the screed smoothly and the rollers had little effect in compacting the pavement to the required density. The distributor truck did not have a calibrated stick nor was it weighed, making it almost impossible to determine the amount of recycling agent being applied. After about an hour of frustration and hair pulling, the inspector stopped all work until the operation could be done properly. This required modification of some procedures and bringing in some new equipment. The original paving screed was only 10 feet wide compared to the 14 foot width being scarified and the roller was to small for the amount of rolling required.

Quality control testing is essential and having the proper equipment is required on each project. Measuring the depth of loose material with a ruler or using a string line as a reference are not very satisfactory ways to determine the depth of scarification. We used them on this project, as we were not familiar with the "Nine Pound Test", which we have used on all subsequent projects.

A test section was included as part of this project. The overlay was deleted to permit visual evaluation of the recycled pavement. The traffic has used a portion of this section for the past year. No failure has occurred due to traffic, however, the pavement has become very flushed and indicates a bleeding tendency. Shortly after construction, the skid number was lower then would be generally expected, in the range of 33-39. Skid tests completed one year after construction showed considerable lowering of the skid number to the high teens in the traveled lanes. Figure 11 shows the condition after one year. The parking lane (foreground) which has a 37 skid number and no traffic, shows no sign of any problem and looks like any 1/2 inch mix.

Roadway appurtenances are items in the traveled roadway which receive little thought such as traffic detectors, man holes, valve covers, survey monuments, etc. The latter are all made of cast iron or steel and do not present any problem to the contractor during the heating and scarifying operation. They are not affected by the heat and the spring loaded tines permit them to ride up and over these covers without any adverse effect on the scarification of the surface. Traffic detectors present a different type of problem. Inductive loop or magnitometer type detectors are not affected by the heat, but if the tines are not raised in the area of the wires, they will be pulled out of the pavement necessitating replacement. An acceptable procedure is to lift the tines approximately one foot before they get to the detectors and then lower them into the pavement again about a foot beyond the detectors. The old style pressure detectors require two strategies. If the rubber pad is in place it must be protected from the heat and the tines must be lifted as the rubber will soften and burn. If the detector is out of service and the rubber pad has been removed, the filler material may or may not react adversely. The surface of the epoxy-sand mixture burned but after the tines passed over it the fire was out and no damage was apparent. Raised pavement markers need to be removed as should heavy accumulations of traffic paint. The paint chars and with a 19 year accumulation was of such thickness that it flaked off in large pieces, 1-3 inches in diameter. The cross walk and pavement markings were much more bothersome then the lane lines.

Laboratory testing after construction was confined to skid testing and analysis of core samples obtained periodically. Abson recovery tests were performed on the core samples obtained over the past year. The viscosity test results indicate that the recycling agent takes quite some time to soften the asphalt. Figure 12 is a plot of the Viscosity - Time relationship for this project. The time delay indicated may account in part for the change in surface conditions previously noted in the test section. This and other projects will continue to be monitored and tested.

Additional studies appear to be warranted to evaluate the laboratory tests performed prior to construction.

As the result of this project several lessons were learned.

A detailed specification is required to protect both parties, see Appendix C.

Quality control testing is essential during construction.

Meet with contractor and go over all aspects before starting work.

Require paving machine vibrating screed or tamper bar to be extended to the same width, as the width to be scarified.

Mark out location of traffic detectors.

An overlay is necessary to maintain a roadway with a high skid number.

Recycling agents take time to react, with aged asphalt.

Surface recycling with a one inch overlay has retarded reflection cracks for the first year and can be expected to so for a much longer period.

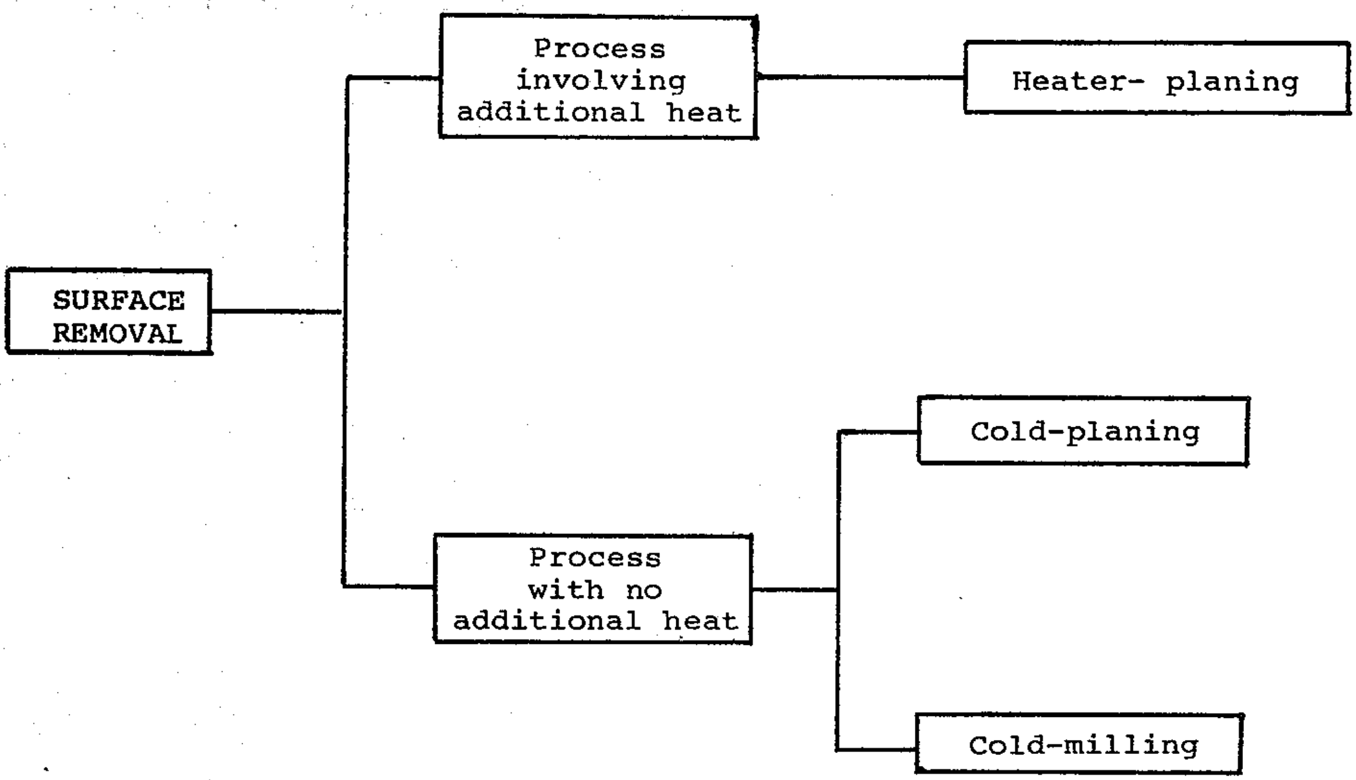


Figure 1

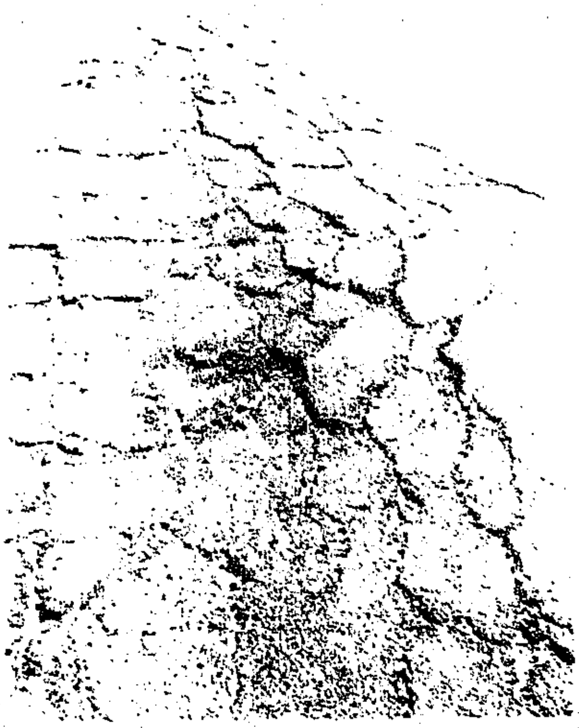


Figure 2

Figure 3

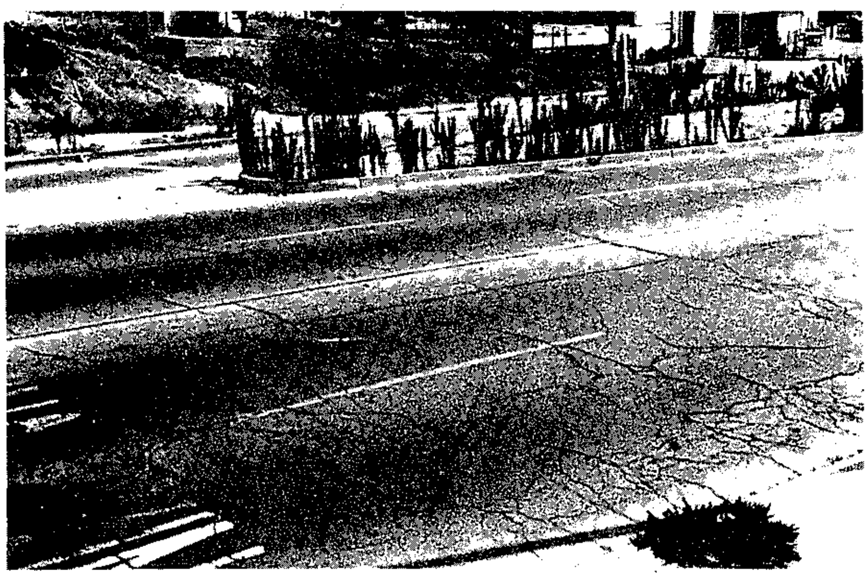
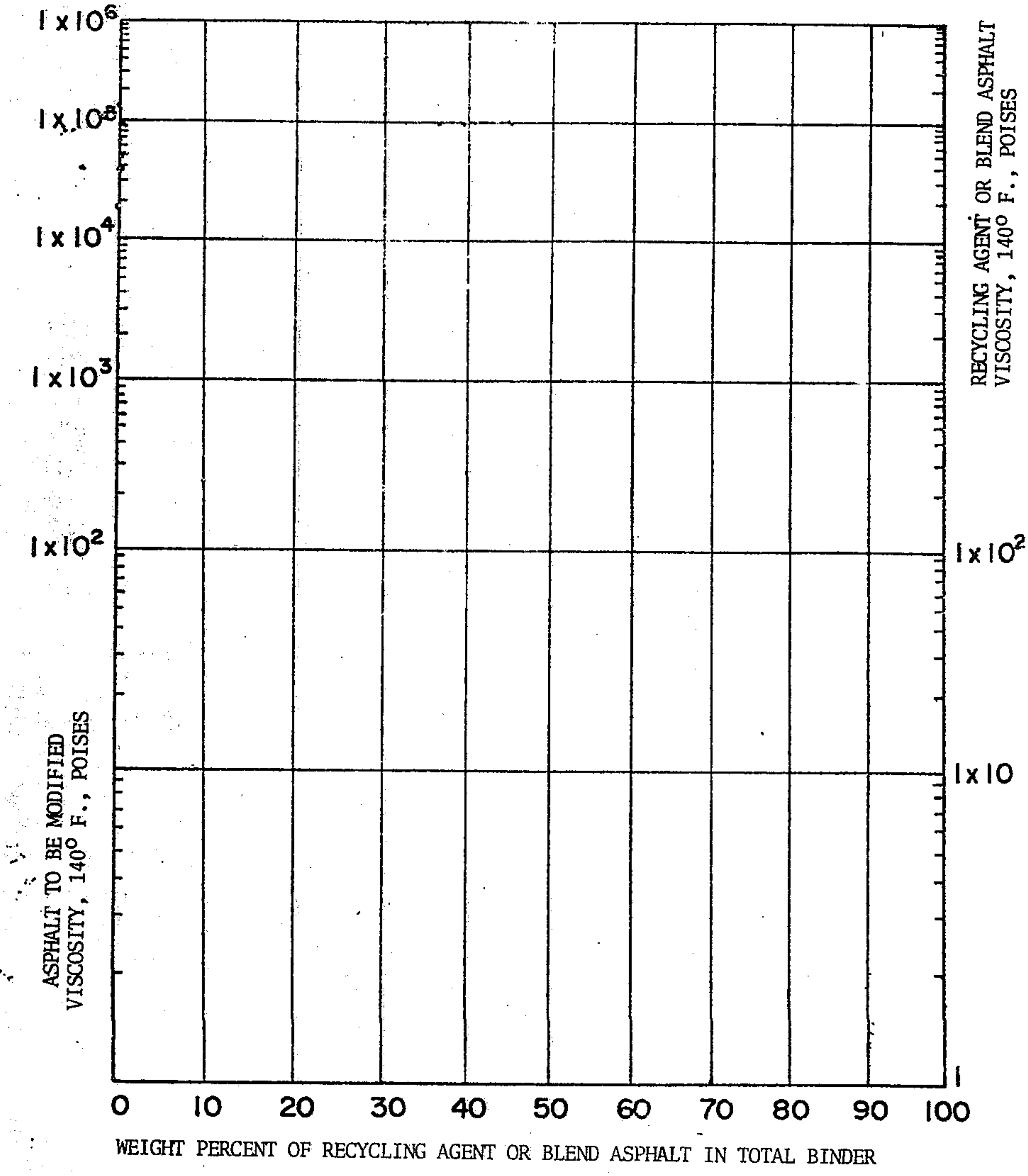
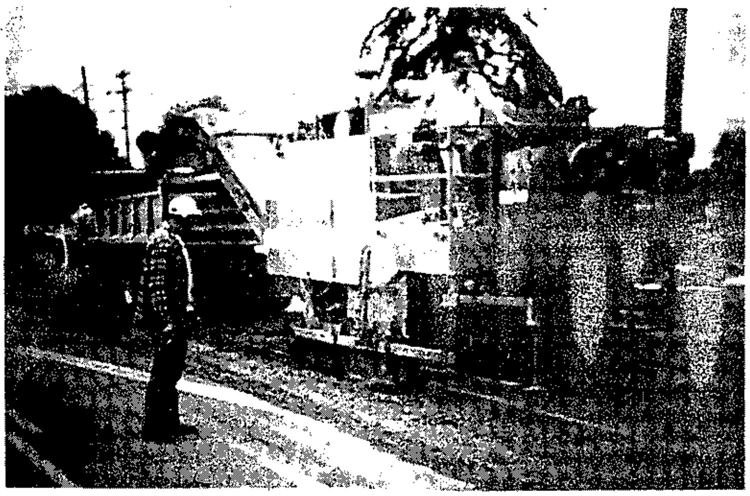


Figure 4



NOMOGRAPH FOR VISCOSITY

Figure 5



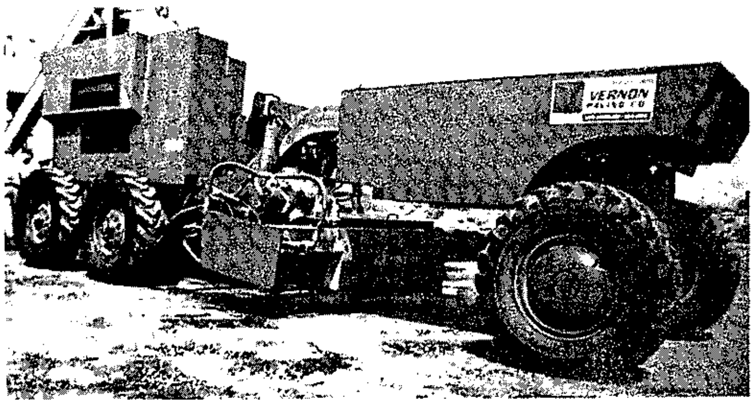
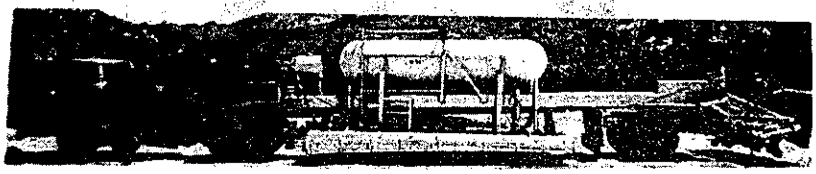


Figure 6



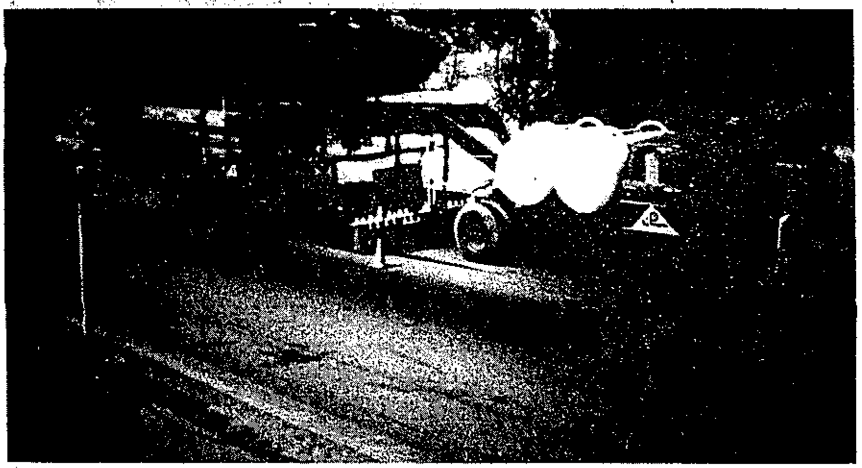
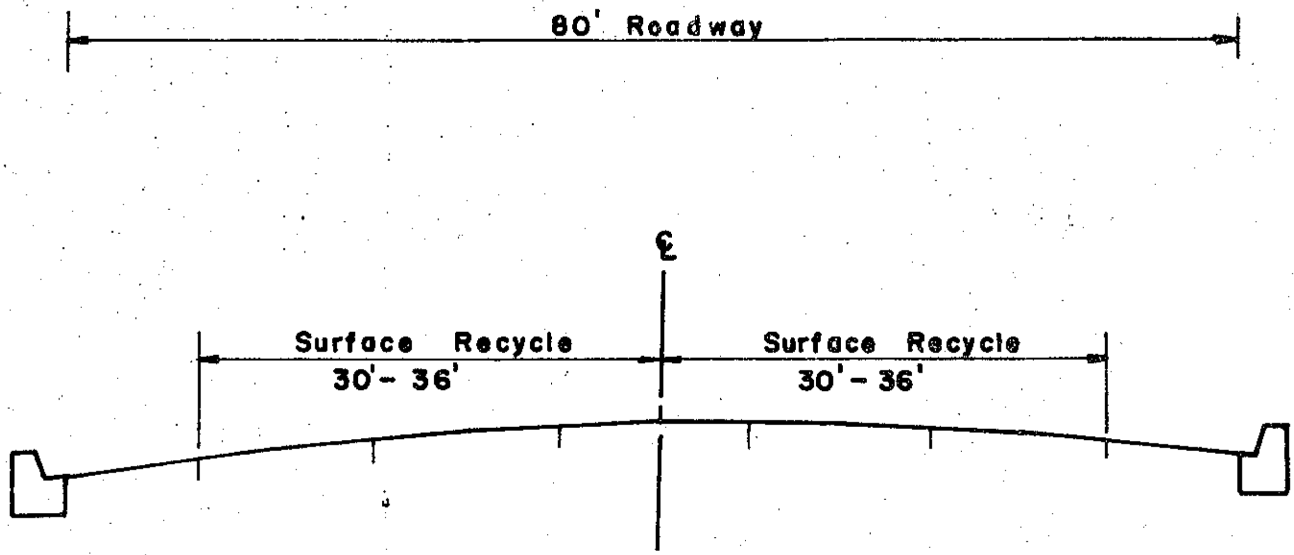
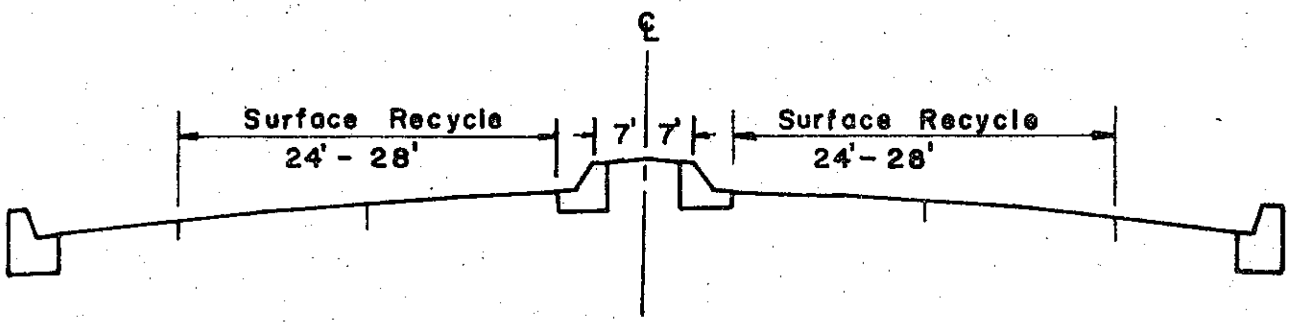


Figure 7



Requires 5 passes of heater-scarifier

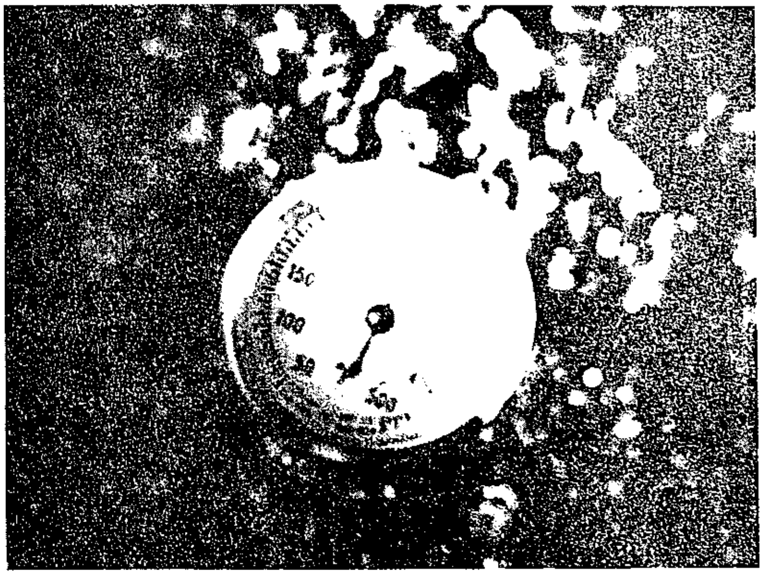
if median area and left turn pockets recycled



Requires 4 passes of heater-scarifier

omit the left turn pockets

Figure 8



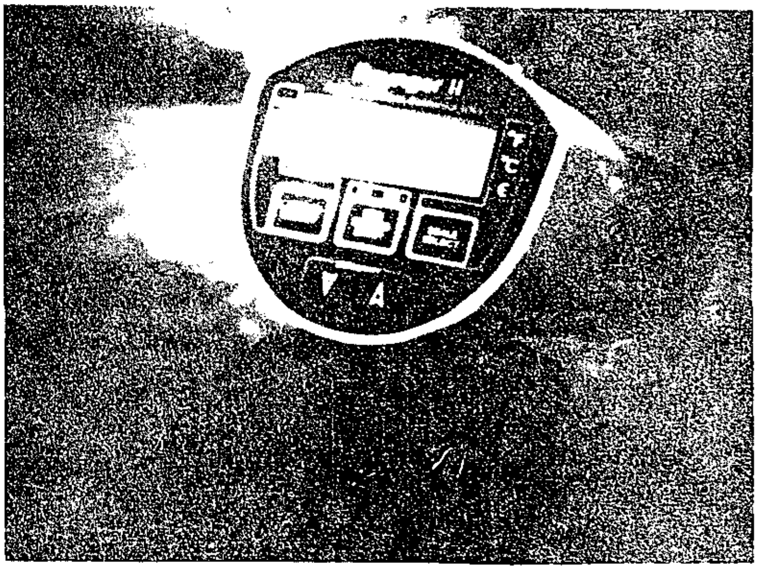
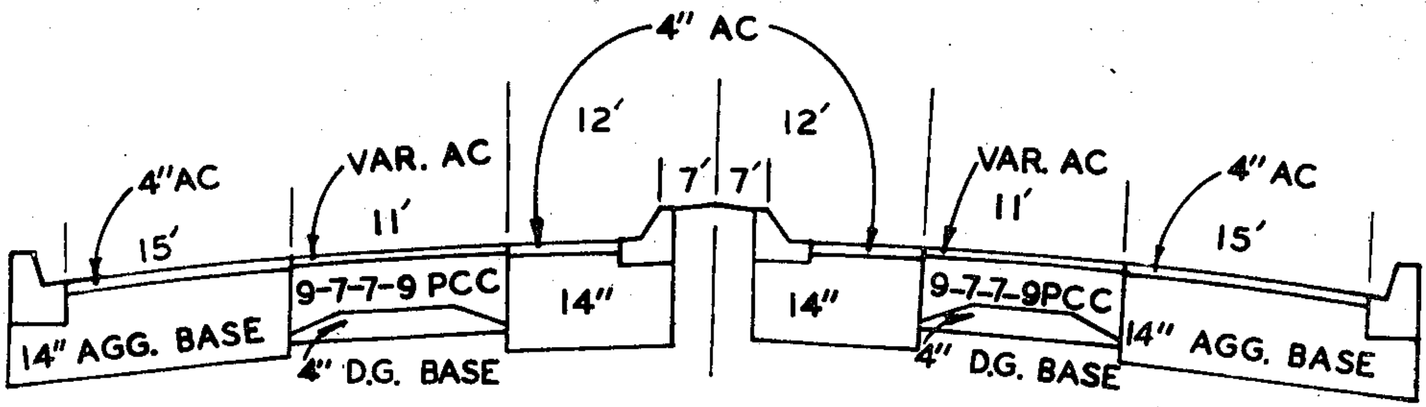
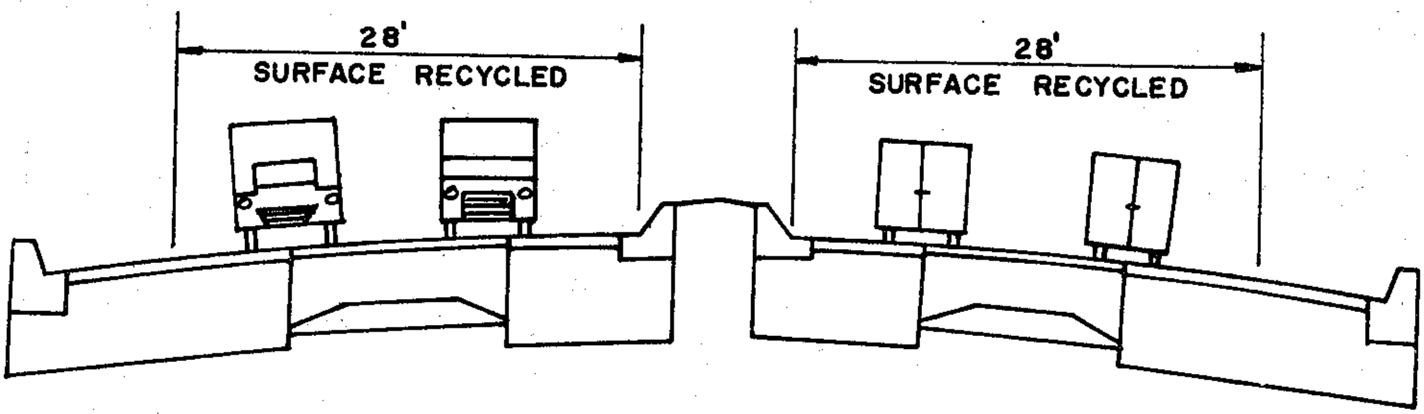


Figure 9



CONSTRUCTED 1961



WESTERN AVENUE

TRAFFIC PATTERN

Figure 10

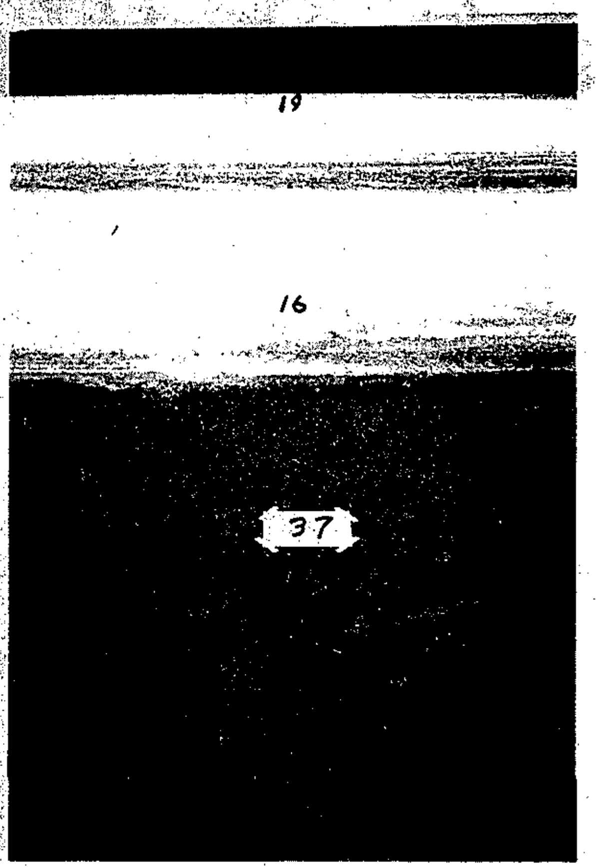


Figure 11

VISCOSITY VS AGE

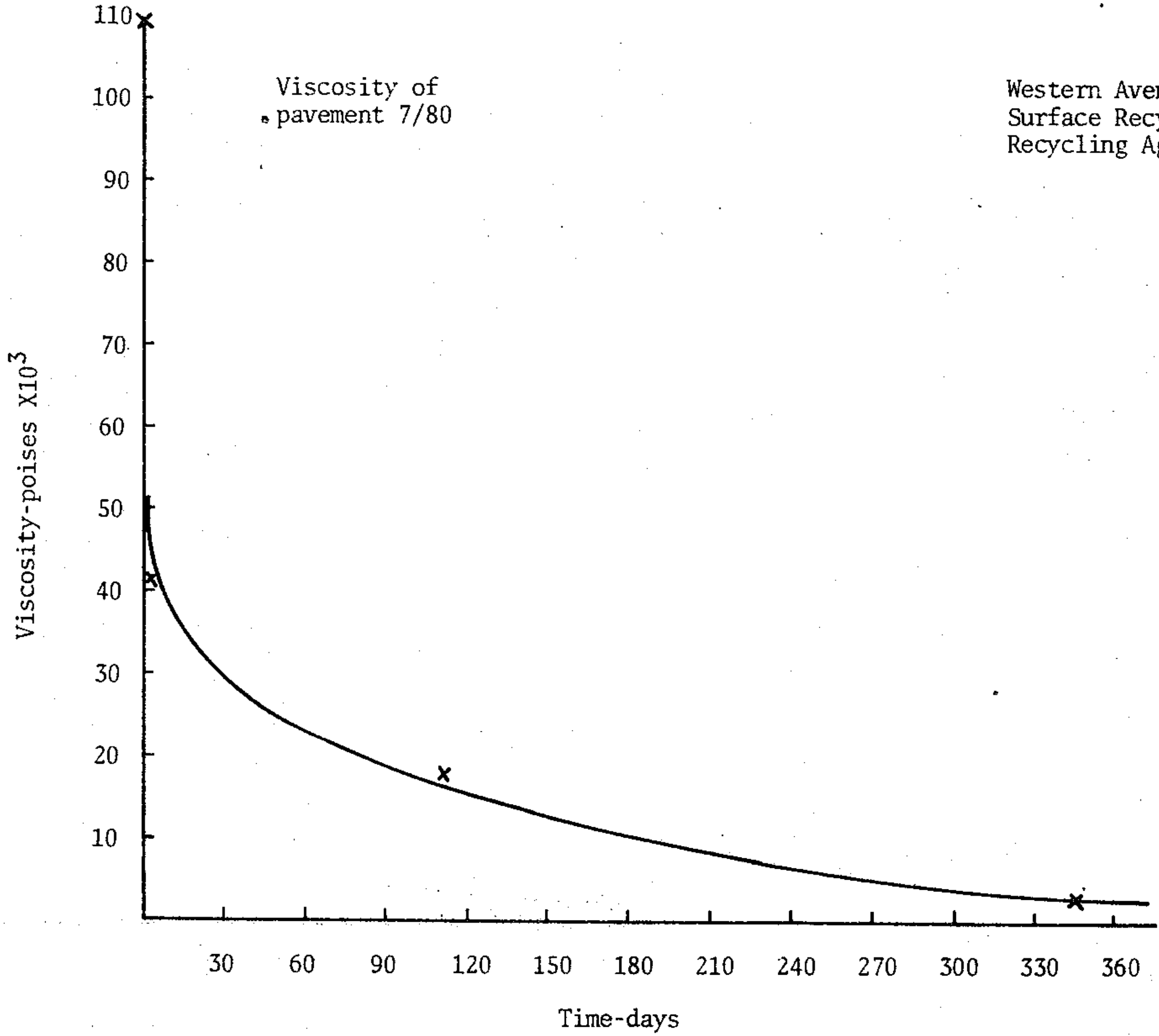


Figure 12

Proposed Specifications for
Hot-Mix Recycling Agents[1]

TEST	ASTM TEST Method	RA-5 min.	RA-5 max.	RA-25 min.	RA-25 max.	RA-75 min.	RA-75 max.	RA-250 min.	RA-250 max.	RA-500 min.	RA-500 max.
Viscosity @ 60°C (140°F), cSt	D2170 or 2171	200	800	1000	4000	5000	10000	15000	35000	40000	60000
Flash Point COC, °C (°F)	D92	204(400)	-	218(425)	-	232(450)	-	232(450)	-	232(450)	-
Saturates, wt. %	D2007	-	30	-	30	-	30	-	30	-	30
Residue from RTF-C Oven Test @ 325°F	D2872[2]										
Viscosity Ratio[3]	-	-	3	-	3	-	3	-	3	-	3
RTF-C Oven weight Change, ±, %	D2872[2]	-	4	-	3	-	2	-	2	-	2
Specific Gravity	D 70 or D1298	Report		Report		Report		Report		Report	

1. The final acceptance of recycling agents meeting this specification is subject to the compliance of the reconstituted asphalt blends with current asphalt specifications.

2. The use of ASTM D1754 has not been studied in the context of this specification, however, it may be applicable. In cases of dispute the reference method shall be ASTM D2872.

3. Viscosity Ratio = $\frac{\text{RTF-C Viscosity at 60°C (140°F) cSt}}{\text{Original Viscosity at 60°C (140°F) cSt}}$

Table 1

Suggested Limiting Values
Medium-Setting Emulsified Recycling Agents

Tests on Emulsions	RAE-1M	RAE-5M	RAE-25M	RAE-75M	RAE-250M	RAE-500M
Vis., SSF @ 50°C, Sec.	50-450	50-450	50-450	50-450	50-450	50-450
Storage Stability Test, 1 day, w%, max.	1.0	1.0	1.0	1.0	1.0	1.0
Coating Ability and Water Resistance						
Coating,						
dry aggregate	good	good	good	good	good	good
after spraying	fair	fair	fair	fair	fair	fair
wet aggregate	fair	fair	fair	fair	fair	fair
after spraying	fair	fair	fair	fair	fair	fair
Particle Charge Test	positive	positive	positive	positive	positive	positive
Sieve Test, w%, max.	0.1	0.1	0.1	0.1	0.1	0.1
Distillation:						
Oil Distillate by vol. of emulsion, %, max.	6	10	12	15	15	15
Residue, w%, min.	60	60	60	60	60	60
Tests on Residue from Distillation Test:						
Vis. @ 60°C, cSt	50-150	200-800	1,000-4,000	5,000-10,000	15,000-35,000	40,000-60,000
Saturates, w%, max.	30	30	30	30	30	30
Viscosity Ratio,* max.	3	3	3	3	3	3

$* \dfrac{\text{RTF-C Vis. @ 60°C, cSt}}{\text{Residue Vis. @ 60°C, cSt}}$

Suggested Limiting Values
Slow-Setting Emulsified Recycling Agents

Tests on Emulsions	RAE-1S	RAE-5S	RAE-25S	RAE-75S	RAE-250S	RAE-500S
Vis., SSF @ 25°C, sec.	20-100	20-100	20-100	20-100	20-100	20-100
Storage Stability Test, 1 day, w%, max.	1.0	1.0	1.0	1.0	1.0	1.0
Particle Charge Test	positive	positive	positive	positive	positive	positive
Sieve Test, w%, max.	0.1	0.1	0.1	0.1	0.1	0.1
Cement Mixing Test, w%, max.	2.0	2.0	2.0	2.0	2.0	2.0
Distillation:						
Oil Distillate by vol. of emulsion, %, max.	3.0	3.0	3.0	3.0	3.0	3.0
Residue, w%, min.	57.0	57.0	57.0	57.0	57.0	57.0
Tests on Residue from Distillation Test:						
Vis. @ 60°C, cSt	50-150	200-800	1,000-4,000	5,000-10,000	15,000-35,000	40,000-60,000
Saturates, w%, max.	30	30	30	30	30	30
Viscosity Ratio,* max.	3	3	3	3	3	3

$* \dfrac{\text{RTF-C Vis. @ 60°C, cSt}}{\text{Residue Vis. @ 60°C, cSt}}$

Table 2

Tentative
ARIZ 822
Sept. 1980
(8 Pages)

DETERMINATION OF ADDITIVE OR ASPHALT BLEND REQUIRED FOR MODIFICATION OF ASPHALT VISCOSITY

(An Arizona Method)

Scope

1. This procedure is applicable to the modification of asphalt viscosity by the use of additives or blending asphalts. Section 4 is used in the determination of additive quantities. Methods for determining emulsified additive quantities and also spread rate in gallons per square yard for spray applications are provided. Section 5 is used in the blending of asphalts.

Apparatus

2. The apparatus shall consist of the following:

(a) The apparatus as listed in AASHTO T 202 - "Absolute Viscosity of Asphalts".

(b) The apparatus as listed in AASHTO T 201 - "Kinematic Viscosity of Asphalts", when additives are used.

(c) The apparatus listed in either AASHTO T 227 - "Density, Specific Gravity or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method" or AASHTO T 228 - "Specific Gravity of Semi-Solid Bituminous Materials" (refer to paragraph 4(b)), when additives are used.

(d) The apparatus as listed in AASHTO T 59, Section 13 - "Testing Emulsified Asphalts (Residue by Evaporation)", shall be required when testing with emulsified additives.

Sample Preparation

3. (a) Samples of the materials to be used shall be obtained according to AASHTO T 40 - "Sampling Bituminous Materials".

(b) Sufficient amount of additive residue shall be obtained by ARIZ 504 - "Vacuum Recovery of Asphalt Emulsion Residue", when emulsified additives are used.

(c) In the case of modifying asphalt in existing bituminous mixtures, the asphalt shall be recovered from a sample of the mixture according to ARIZ 413 - "Extraction of Asphalt from Bituminous Mixtures by Soxhlet Extraction" and ARIZ 511 - "Recovery of Asphalt from Extraction Solution".

Procedure (For determination of additive quantities)

4. (a) When using emulsified additives, the percent residue shall be determined by use of AASHTO T 59. (Percent of residue may also be determined by heating 5 gram samples until the moisture has been removed. In the case of dispute AASHTO T 59 shall be used.)

(b) The absolute viscosity of the asphalt to be modified is determined by AASHTO T 202. The kinematic viscosity, centistokes at 140° F., of the additive (residue if using emulsified additive) shall be determined by AASHTO T 201. The specific gravity shall be determined by AASHTO T 227 (for materials with maximum viscosity of 5000 centistokes) or AASHTO T 228 (for materials with viscosities above 5000 centistokes). The absolute viscosity of the additive (or residue), in poises, is then determined by multiplying the kinematic viscosity by the specific gravity and dividing by 100.

(c) By reference to the chart in Figure 1, the quantity of additive required to modify the viscosity to a desired level may be determined. The absolute viscosity of the asphalt to be modified is found on the left side of the chart. The viscosity of the additive is found on the right side of the chart. A line is drawn between the two points. The desired viscosity of the modified asphalt is found on the chart and by following a straightedge horizontally, the line will be intercepted. From this intercept a vertical line to the bottom of the chart will indicate the percent of additive required as a percentage of the total binder (by weight). An example is shown in Figure 1 for the following data:

1) Absolute viscosity of the asphalt to be modified = 34,000 poises.

2) An emulsified recycling agent has been selected to be used as the additive. It has been determined that the residue has an absolute viscosity of 5 poises. By AASHTO T 59 it has been determined that the emulsion has 63% residue.

3) By following the instruction above, the amount of additive required is determined to be 22% of the total binder (by weight), for a desired viscosity of 2000 poises.

(d) When emulsified additives are used, the amount of emulsion must be calculated so that the desired percent additive is achieved:

1) Calculate the amount of emulsified additive required, "A_e".

$$A_e = \frac{(100) \times (A_p)}{E_r\,(100 - A_p)} \times A_a$$

Where: A_a = amount of asphalt to be modified

A_p = percent additive required (From Figure 1.)

E_r = percent of residue in the emulsified additive

Example: (For A_a = 1200 tons, A_p = 22%, E_r = 63%)

$$A_e = \frac{(100) \times (22)}{63(100 - 22)} \times 1200 = 537.2 \text{ tons}$$

2) The percent emulsified additive as a percentage of the total binder (by weight), "P_e", may be calculated:

$$P_e = \frac{A_e}{A_e + A_a} \times 100$$

Example:

$$P_e = \frac{537.2}{537.2 + 1200} \times 100 = 30.9\%$$

(e) If an emulsified additive is to be applied by spraying a scarified and recompacted bituminous surface, the required amount of additive may be calculated in gals./sq. yd. by the following:

1) Determine the density (lbs/cu. ft.) of the material to be scarified by AASHTO T 166 - "Bulk Specific Gravity of Compacted Bituminous Mixtures". (The specimens for testing shall be obtained by coring the existing pavement and then removing the top of core by sawing at the depth of scarification.)

2) Determine the percent asphalt in the portion of the existing pavement to be scarified by ARIZ 413 - "Extraction of Asphalt from Bituminous Mixtures by Soxhlet Extraction" or ARIZ 402 - "Bitumen Content of Bituminous Mixtures by Vacuum Extraction".

3) Determine the weight, in lbs., of bituminous mixture in one square yard of scarification, "W_m":

$$W_m = (D_m)\ (9)\ (D_s)$$

Where: D_m = Density of existing material (lbs./cu. ft.)

D_s = Depth of scarification (in decimal feet)

Example: (For D_m = 140 lbs./cu. ft., D_s = 3/4" = 0.0625')

$$W_m = (140)\ (9)\ (0.0625) = 78.75 \text{ lbs.}$$

4) Determine the weight of asphalt to be modified in scarified material (for one square yard), "A_a":

$$A_a = (W_m)\ (P_s)$$

Where: P_s = percent asphalt in existing material (expressed as a decimal)

Example: (For $P_s = 5.5\% = 0.055$)

$$A_a = (78.75 \text{ lbs.})\ (0.055) = 4.33 \text{ lbs.}$$

5) Determine the weight of emulsified additive in lbs., "A_e", required to modify the asphalt in one square yard of scarified material:

$$A_e = \frac{(100) \times (A_p)}{E_r\ (100 - A_p)} \times A_a$$

Where: A_a = amount of asphalt to be modified

A_p = percent additive required (From Figure 1.)

E_r = percent of residue in the emulsified additive

Example: (For $A_p = 22\%$, $E_r = 63\%$)

$$A_e = \frac{(100) \times (22)}{63(100 - 22)} \times 4.33 = 1.939 \text{ lbs./sq. yd.}$$

6) Determine the application rate in gals/sq. yd., "A_r":

$$A_r = \frac{A_e}{E_w}$$

Where: E_w = weight of emulsion, lbs. per gal.

Example: (For E_w = 8.33 lbs./gal.)

$$A_r = \frac{1.939 \text{ lbs./sq. yd.}}{8.33 \text{ lbs./gal.}} = 0.23 \text{ gals./sq. yd.}$$

Note: When the additive is to be used on a heater scarified section of existing pavement, the quantity obtained by the above method necessarily assumes that all of the asphalt in the scarified section will be modified by the additive.

Procedure (For blending asphalts)

5. (a) The absolute viscosities of the asphalt to be modified and the blend asphalt to be used are determined by AASHTO T 202.

(b) By reference to the chart in Figure 2, the absolute viscosity of the asphalt to be modified is plotted on the left side of the chart. The absolute viscosity of the blend asphalt is plotted on the right side of the chart. A line is drawn which connects the two points. The desired viscosity of the modified asphalt is found on the chart. By following a straightedge horizontally, the line will be intercepted. From this intercept a vertical line to the bottom of the chart will indicate the percent of blend asphalt which is required as a percentage of the total binder (by weight). An example is shown in Figure 2 for the following data (The nomograph used in Figure 2 is the same as in Figure 1, but to illustrate the procedure for blending asphalts a separate chart is used.):

1) Absolute viscosity of the asphalt to be modified = 16,000 poises.

2) Absolute viscosity of the blend asphalt = 1,000 poises.

3) By following the instructions above, the amount of blend asphalt required is determined to be 45% of the total binder (by weight), for desired viscosity of 4,000 poises.

Precision

6. The use of this procedure will generally yield close approximations in achieving the desired modified viscosity. A trial mix should always be made to check the actual viscosity.

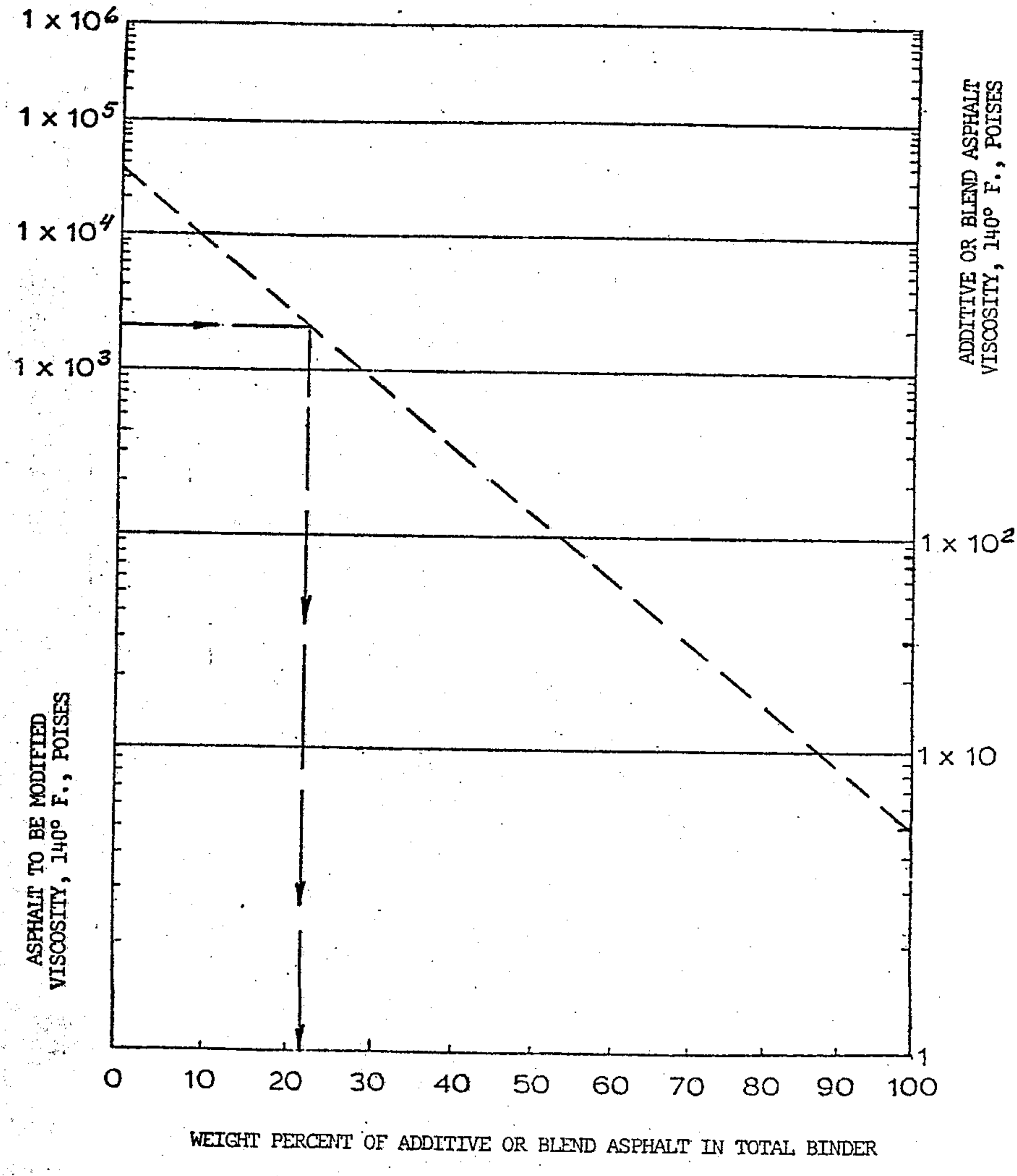


FIGURE 1 - NOMOGRAPH FOR VISCOSITY

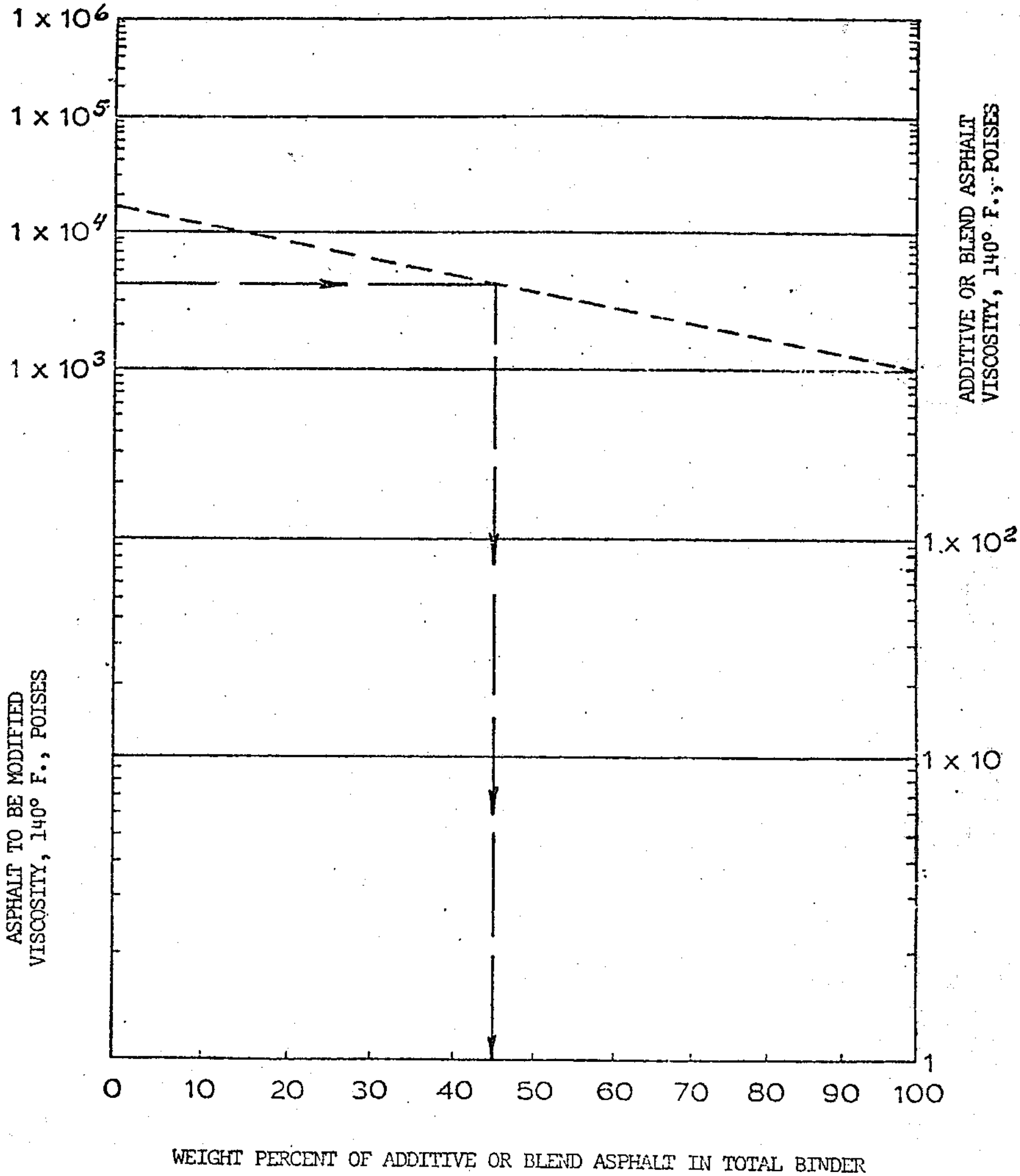


FIGURE 2 - NOMOGRAPH FOR VISCOSITY

Appendix A

COLD MILL AC PAVEMENT

The Contractor shall cold mill existing AC pavement, as dimensioned and as otherwise designated on the Plans. Cold milling shall remove variable depths of AC to provide an overlay key at joins and over the width of the cold milled area. Additional widths of cold milling may be required at various locations as determined by the Engineer. The surface of pavement after milling shall be uniformly rough grooved or ridged as directed by the Engineer. The grade shall not deviate from a suitable straight edge by more than 3/8" at any point.

The Contractor shall remove existing AC overlay from gutters adjacent to any area specified to be cold milled, as directed by the Engineer.

The milling machine shall be specially designed and built to perform cold milling of bituminous pavement with the ability to mill concrete patches. The cutting drum shall be a minimum 60" wide with carbide tip cutting teeth placed in variable lacing pattern to produce various finishes. The machine shall be capable of operation at speeds of from 0 to 40 FPM. It shall be self-propelled and have a water spray at the cutting drum to minimize dust. The machine shall be capable of removing the material next to the gutter of the pavement being reconditioned and so designed that the operator thereof can at all times observe the milling operation without leaving the controls. The cutting drum shall be adjustable as to slope and depth and shall deep cut in one pass a maximum of 3" without producing fumes or smoke. The milling machine shall have previously performed satisfactorily on similar work.

The Contractor shall provide a smaller machine to trim areas inaccessible to the larger machine at manholes, curb returns and intersections. The smaller machine shall be equipped with a 12" wide cutting drum mounted on a 3-wheel chassis allowing it to be positioned without interrupting traffic or pedestrian flow.

During the operation, the Contractor shall sweep the street with mechanical equipment and remove all loosened material from milled areas. The Contractor shall abate dust nuisance by cleaning, sweeping and sprinkling with water or other means as necessary.

Before cold milling pavement within 300' of a traffic signal, the Contractor shall notify Mr. J. E. Hendershot at (213) 226-8174, at least 3 working days prior to commencing work within said area. Upon notification, the Agency will mark the location of all existing loop detectors. The Contractor shall not cold mill within 12" of these loop detector conductors.

Damage to the existing loops caused by the Contractor's operation will require replacement of the loops in their entirety at the Contractor's expense.

Full compensation for complying with the above requirements shall be considered as included in the unit price bid for COLD MILL AC PAVEMENT.

SPECIAL PROVISIONS FOR CASH CONTRACT NO. ______

HEATER-SCARIFYING AC PAVEMENT

GENERAL

Heater-scarifying shall consist of furnishing all labor, equipment and materials and performing all operations in connection with processing the existing asphalt concrete pavement in place by heating, scarifying, remixing, spreading, screeding, compacting and applying a recycling agent. This work shall be done as indicated on the Plans and as specified herein.

EQUIPMENT

Heaters shall comply with the requirements of the South Coast Air Quality Management District. The Contractor shall obtain the required operating permits from said District. Heaters shall have controls on the individual burners such that the surface temperature immediately behind the heating chamber will not vary by more than 25°F across the width of the heated area. Heaters shall have a minimum rating of 10,000,000 BTU's per hour. The heating chamber shall have a minimum length of 18 feet. All heaters used shall have the same width heating chamber.

The last heater in the heating train shall be equipped with at least two rows of spring equalized scarifier teeth in uniform contact with the pavement and incorporating an automatic release for passing over manholes and valve covers. The width of the scarified pavement shall be the same as the heating chamber. The transverse spacing of the teeth shall be such that at least 90% of the aggregate shall be remixed by spinning or tumbling. The aggregate shall not be pulverized, spalled or broken after scarification. The remixed material shall be spread evenly.

A machine designed for the placement of asphalt concrete shall be used to spread and distribute the scarified material and shall be equipped with a vibrating screed which produces a surface texture of uniform appearance. All vibrating screeds and tamping bars, if utilized on the machine, shall be the same width as the scarified material. This machine shall have the capacity to carry 3 tons of asphalt concrete in a hopper for distribution to the screed as needed. The screeded material shall be compacted by a vibratory type steel wheel compactor complying with the requirements of Subsection 302-5.5.1 of the Standard Specifications.

The distributor truck for the recycling agent shall conform to the requirements of Subsection 203-2.5 of the Standard Specifications.

HEATER-SCARIFYING AC PAVEMENT (Cont.)

RECYCLING AGENT

The recycling agent used on this project shall be RAE-5S and spread at the rate of 0.12 to 0.20 gallon per square yard as directed by the Engineer. The recycling agent shall be delivered undiluted and conform to the following requirements:

EMULSIFIED RECYCLING AGENTS

Tests on Emulsions	Test Method ASTM	RAE-5S Min.	RAE-5S Max.	RAE-25S Min.	RAE-25S Max.
Viscosity @ 25°C, SSF	D244	20	100	20	100
Storage Stability 1 day, %	D244	-	1.0	-	1.0
Cement Mixing Test, %	D244	-	2.0	-	2.0
Sieve Test, %	D244 (1)	-	0.1	-	0.1
Particle Charge Test	D244	Positive		Positive	
Distillation:					
Oil Distillate by vol. of emulsion, %	D244	-	3.0	-	3.0
Residue, by weight, %	D244	57	-	57	-
Tests on Residue from Distillation Test:					
Viscosity @ 60°C, cSt	D2170	200	800	1000	4000
Viscosity Ratio (2)	D2170	-	3.0	-	3.0
Saturates, %	D2007	-	30	-	30

(1) Test procedure indentical with ASTM D244 except that distilled water shall be used in place of 2% sodium oleate solution.

(2) Viscosity Ratio = $\dfrac{\text{RTF-C Viscosity @ 60°C, cSt}}{\text{Original Viscosity @ 60°C, cSt}}$

HEATER-SCARIFYING AC PAVEMENT (Cont.)

CONSTRUCTION DETAILS

The ambient temperature shall be at least 50°F during the heater-scarifying operation. If, in the opinion of the Engineer, weather conditions or other factors would be detrimental to obtaining a satisfactory result, the operations shall cease. Prior to commencing heater-scarifying operations the existing pavement shall be cleaned .. all extraneous materials. Power brooms shall be supplemented where necessary by hand brooming and such other tools as required to bring the surface to a clean, suitable condition, free of all deleterious materials.

The number of heater units utilized shall be determined by the Contractor. Multiple heater units shall be utilized in tandem such that the heat emitted will soften the asphalt concrete for the required depth for the entire width of the heating chamber and scarifier but not more than 6 inches beyond the scarified area. The surface of the pavement shall not be heated to a temperature higher than 400°F. The temperature of the scarified material shall be between 250°F and 325°F when measured immediately behind the scarifier. No uncontrolled heating causing differential softening of the asphalt concrete will be permitted.

The weight of the existing asphalt concrete has been assumed to be 144 pounds per cubic foot. On this basis, a minimum of 9 pounds per square foot of the existing asphalt concrete surface shall be scarified. If the specified amount is not being scarified, the work shall be stopped and shall be resumed only after the Contractor has made the needed adjustments and the Engineer is satisfied that this requirement can be met.

The scarified material shall be spread and distributed by machine. Three tons of Class C2-AR-8000 asphalt concrete shall be placed in the hopper of said machine at the beginning of the day to provide sufficient material in front of the screed to assure a smooth and uniform cross section. A tarp shall be placed over this material to help retain the heat throughout the day.

The scarified material shall be compacted immediately after it has been distributed and leveled and while its temperature still is in excess of 235°F.

Within 30 minutes after compaction the recycling agent shall be applied. No material to which the recycling agent has been applied shall be reheated or rescarified. Traffic shall not be permitted on the compacted material for a least 60 minutes after the recycling agent has been applied. If the Engineer determines that excessive raveling is occuring, this time may be extended.

HEATER-SCARIFYING AC PAVEMENT (Cont.)

CONSTRUCTION DETAILS (Cont.)

At the end of a day's run, the last 30 feet of scarified material shall be spread and compacted as usual but the recycling agent shall not be applied. On the next day the heaters may reheat this section to provide for proper scarification depth when they start scarifying the next section of roadway. At the end of the day, the material in the hopper and in front of the screed of the paving machine shall be removed from the project site and discarded.

Should the Contractor shut down its operation for more than 15 minutes, the above procedure shall be followed. Additionally, the excess material shall be spread in front of the screed on the non-scarified pavement in a thin lift, 1/4 - 3/8 inches, for reheating, only if it is anticipated that the operation will resume the same day.

Before heater scarifying pavement within 300' of a traffic signal, the Contractor shall notify Mr. J. E. Hendershot at (213) 226-8174, at least 3 working days prior to commencing work within said area. Upon notification, the Agency will mark the location of all existing loop detectors. The Contractor may heat the area where traffic sensing devices are embedded in pavement but shall lift the scarifiers to protect such equipment and wires.

Damage to the existing loops caused by the Contractor's operation will require replacement of the loops in their entirety at the Contractor's expense.

The amount of material scarified shall be determined in accordance with the requirements of Arizona Test Method 409.

The crew shall be composed of a non-working supervisor at the project site at all times, an operator for each piece of equipment, one screed operator, two rakers and a sufficient number of laborers to fully perform the operation.

PROTECTION OF EXISTING IMPROVEMENTS

Since high temperatures are required in the heater-scarifying operation, the Contractor shall exercise care against possible injury or damage to existing improvements. The Contractor shall protect all existing curbs, gutters, trees, shrubbery and other improvements from damage. Smaller parkway trees shall be protected by shields and overhanging trees may be sprayed with water to inhibit damage. No machine with an open flame exhaust will be permitted. Adjacent improvements shall be protected from overspraying of the recycling agent. Existing improvements damaged by the Contractor shall be repaired or replaced to the satisfaction of the Engineer at the Contractor's expense.

HEATER-SCARIFYING AC PAVEMENT (Cont.)

PUBLIC CONVENIENCE AND SAFETY

In addition to the requirements of Subsection 7-10 of the Standard Specifications, the Contractor shall post C6 signs, "Loose Gravel", at the beginning of the project and at 1/2 mile intervals throughout the length of the project. This requirement applies for both directions of traffic.

EMISSION CONTROL

The Contractor shall minimize the escaping of solids into the air caused by either the machine or the burning of pavement during the heating operation.

In the event that a smoke problem develops and becomes excessive, it may be necessary to add additional blower systems or other devices or to remove the contaminant by cold milling. No additional compensation will be allowed for any extra steps required to reduce emissions.

MEASUREMENT AND PAYMENT

Heater-scarifying of the pavement will be paid for at the contract unit price per square yard. Such price shall constitute full compensation for the item complete as herein described and specified.

Recycling agent will be paid for at the contract unit price by certified weight. The certified weight shall be determined per Subsection 9-1.3 of the Standard Specifications. The unit price shall include full compensation for furnishing and applying the recycling agent.

Question and Answers
Recycling Seminar
Sacramento, California
September 16, 1981

Q - Wally Ames: Caltrans

What are the implications where cold and hot recycling inculdes fabric?

A - Doug Bernard:

We have been trying to get some of our research funds for this. One fabric company in particular did some research on that. Although it is preliminary, conclusions were that it could be done. The milling machines would have to be slowed to 10' per minute or slower and all the teeth would have to be used. Strips as long as 18" and 1/4" wide would result. I was talking to a contractor just the other day and he had problems milling it so I think we have a potential problem there and I wish to get moving faster in trying to solve it. We are looking into research on it now.

A - Jim Scherocman:

One of the cities in the east purposely laid a pavement with fabric in it and then 3 or 4 months later milled it up just to see if they could or not. A report will be presented in February 1982 at the AAPT meeting in Kansas City by the fabric people, on this research project. Secondly when you get into planing or milling fabric, it wraps around the drum and you can get some problems with it. We have, depending on how long the material has been down, bogged down with it and other times we have cut through it so simple you would hardly know it was there.

A - Tom Scrimsher:

Caltrans hasn't done an awful lot of work on this primarily because the fabric hasn't been down a great length of time - maybe 7 or 8 years. We did take one fabric project in So. Calif. and milled it. This particular fabric was Petromat. It came up fine in strips 2 or 3 inches long by about 1/2" wide. We used this material in both hot and cold recycling under laboratory conditions and we had no problem whatsoever. After contacting people in other states, we learned that some types of fabric will not recycle well, however.

I think any studies of milling or recycling fabric 3 or 4 months after placing may be a little unfair to the fabric industry because we are not going to recycle our pavements when they're that new. I would think 10 or 15 years would be a better time span. I would suspect the fabric would then be in a different physical condition than when it was new. However, we admit we don't have all the answers on fabric as yet.

A - Ray Forsyth:

I would take a more optimistic view than Doug. The vendor that has done some work on this (Petromat) had data that was encouraging, both in the field and in the lab, so I don't think it's an insurmountable problem.

Q - Steve Winkler: Stanislous, CO.

If the Petromat were left in place under 2" or 3" of AC, would heater scarifier recycling damage the fabric?

A - Joe Vicelja:

If you are maintaining your temperature control and allowing about 3/4" depth of heating, you probably won't have any problem. Heat does not penetrate through the asphalt concrete as quickly as you think. The important thing about heater scarifier work is the dwell time. A 30 foot heater will put more heat into the pavement than a 10' heater so you have to be careful.

Q - John Brown: Caltrans

Is Caltrans working on a permissive spec for recycling?

A - Ray Forsyth:

It certainly has been seriously considered. We have a directive requiring recycling be considered for each project. If recycling is not considered, there has to be a valid reason. I would say, John, that it is under consideration.

A - Tom Scrimsher:

When you say permissive spec, can you explain a little bit more to me just what you have in mind?

John Brown:

Essentially, the end result spec like some of the other states are using.

A - Tom Scrimsher:

I beleive end result specs are being considered in many areas, one of which is recycling and, as Ray said, we are pushing recycling without question. Thus we really don't need a permissive spec to recycle if we are trying to use it whenever we can.

Jim Scherocman:

If Caltrans will sit down with the contractors in this state and commit themselves to "X" number of tons or "X" number of sq. yds. of material to be recycled the next 2 or 3 years, you will see recycling get going in this state. You will see the cities and counties recycling while Caltrans is still deciding on how to write the spec. No contractor is going to modify his plant to recycle, unless by a permissive spec he can add salvaged material when he wants and in the amount he wants. If you allow recycling on a project by project basis, we will be here five years from now holding the same discussion.

Joe Vicelja:

While we are talking about the permissive type spec or end result, I don't think we have enough knowledge today in either the private or public sector to know where we are going. I believe we need to do much more testing to determine methods for specs.

Ray Forsyth:

Maybe to defend Caltrans a little, I should say that some of our advertized recycle projects have given the contractor an option - to recycle or used conventional mix. In no case did the contractor select the recycling option. That's why we are having this seminar - to get the contractors familiar with our procedure so they will go a little bit faster. We recognize a permissive spec maybe the next step, but we have to educate a lot of people including our contractors.

Jim Scherocman:

You've got to understand economics. A Contractor given the option to recycle will never recycle. He can't bid his plant conversion costs and compete against a contractor who doesn't have that cost. He has got to have "X" number of tons to spread the conversion cost over - in other words, several projects.

Doug Bernard:

I support Jim's philosophy on that. This month FHWA put out a directive that said asphalt recycling will be allowed on all projects, so that may have some influence toward providing a permissive spec.

Ray Forsyth:

The nice thing about being a moderator is that you get the last word. I agree with Jim - no contractor is going to revamp his operations for one job. But it seems to me with the growing interest in recycling and the fact that Caltrans is actively advertizing so many jobs, that the more inventive contractors would move into it.

Q - Virgil Mustain: El Dorado Co.

Can cold recycling be done through a series of old chip seals?

Jim Scherocman:

We have watched several times when they have gone into some old chip seals and cold mixed it. They have broken up the old pavement, added asphalt emulsion primarily, but sometime cutbacks were used, and relaid the material and they covered it with a thin hot mix surface coarse or another chip seal. Some counties in Ohio have worked for years with cold mixes as John Wood commented. We use to call it stabilization and now we call it recycling. There are no problems with it at all.

Q - Wally Ames: Caltrans

Jim, you made a statement that the contractor should own the salvaged AC. You also said the contractor will probably have his own stockpile of salvaged AC known as a GOK (God only knows) for use in small quantities. This may be alright for local cities or counties, but how do you suggest we follow your plan and implement what you are recommending when California is 1000 miles long and has both urban and rural areas with varying traffic voulumns?

A - Jim Scherocman:

In rural areas you have a question on what to do with the excess material. I think what you need to do first of all is to separate the planing from the recycling. Then the contractor must be permitted to own the salvaged AC and stockpile as he sees necessary.

The contractor must also be allowed to say how much salvaged will be used in the recycled mix. He will maintain final mix quality from his stockpile supply which means he will decide according to the supply how many stockpiles to make and how much of each to use.

Q - Dave Holman: City of Ventura

A number of our streets with thin overlays have asphalt with asbestos added. What are your comments pertaining to environmental concerns when recycling these pavements?

A - Jim Scherocman:

A contractor today recycling pavements with asbestos has to maintain records for 30 years. You have to maintain the health records of your people (employees) for 30 years. Any contractor bidding on recycling an asbestos overlay would be just foolish.

Q - Bob Moore: Caltrans

Are the gravel equivalences used in structural design the same for recycled mixes (hot or cold) as conventional mixes?

A - Tom Scrimsher:

The recycled mixes today in California have be performing comparatively well relative to conventional mixes and so for starters we are presently using the same general factor for recycled and conventional mixes.

A - Jim Scherocman:

Hot recycled mix is essentially the same, but I think a a cold mix is a different animal. I don't think it has the structural strength because of the variations in the material in place. In no way will a cold recycled mix be equivalent to a hot recycled mix. It just can't be and never will be.

Q - Les Jorgenson: Fresno Co.

A recent cold recycling project had material less than 1" after milling which seemed ideal. However, some projects have produced large chunks after milling. What is the cause of it and how can it be corrected?

A - Joe Vicelja:

Primarily the milling is caused by a number of teeth cutting into the pavement. The manufactures of the machine designed it to give you a uniform product but many contractors remove some of the teeth or let them wear excessively and, in both cases, this will effect the fineness of the final grading. Also the direction of cut will influence the graduation. Upcutting will cause the material to break off in chunks in a badly cracked pavement and down cutting will provide finer mixes.

A - Jim Scherocman:

We haven't agreed before so there is no reason to agree now. The two main factors that effect chunk size are the forward speed of the milling machine and the condition of the existing pavement. The faster the speed the larger the chunks and the more alligator cracks that exist in the old pavement the bigger the chunks. If I am upcutting and traveling at 50 feet a minute while making a 2" cut in alligator cracked pavement, we will almost always expect that we will create big chunks or slabs. You do not ever want a down cut with a planer unless you are cutting or removing the total AC depth. While it is true a downcut can control chunk size better due to a shearing action, the machine will walk out of the cut if all the AC is not removed and if someone is standing in front of the machine they may actually get run over. We emphasize do not downcut unless full depth cutting is required. By far most milling machines today are equipped to upcut.

A - Tom Scrimsher:

What Jim says, of course, about reasons for chunking is true, but what hasn't been said is how the chunks that are ocassionally created are reduced in size. Of course, oversize must be scalped and crushed or pulverized in one way or another. Recently on a cold recycle project on Rt. 395, a unique system was tried. A set of vibrating screens and a roll crusher were mounted on a flatbed trailer and the trailer was attached to and behind a Roto Mill. As the Roto Mill ground pavement, the subsequent millings were lifted up by conveyer and deposited onto the screens on the trailer. The material passing a 1 1/2" screen sifted through and was deposited in a windrow on the street below the trailer. The oversize on the screen trickled to the rear of the screen and into a roll crusher. The resultant crushed material was also deposited on the windrow. Thus a continuous milling, scalping and crushing operation was sucessfully accomplished. The subcontractor for the milling was the Valentine Construction Co. He deserves a lot of credit for his engineering.

Q - Roger Smith: Caltrans

How are the softening agents accounted for in the design stage using trial mixes and are there any studies now to consider the long-term softening effect?

A - Joe Vicelja:

We propose to look into that now. The type of plant will have an effect. A batch plant usually will get softer faster than a dryer-drum.

A - Jim Scherocman:

If you want to prove softening agents will soften the old asphalt, run an Abson recovery. I absolutely guarantee that all tests will show ideal softening and you will be perfectly happy with the results (laughter). Frankly the only way I know to find out if you have a blend or not was tried in Utah and Iowa using a system of scalping the +4 agg. in the mix, adding a dry sand to the recycled mix, remixing and then running an Abson recovery of each fraction.

A - Tom Scrimsher:

Roger, as far as Caltrans is concerned we are designing for the immediate viscosity of a mix and basing recommendations on visual appearance and stability. We are exploring the use of Chevron's Mr test to record long-term softening and, if successful, will use this data as part of future design criteria. This is a dynamic non-destructive test that may be applied to the same test specimens over a long period of time.

Q - Harold Schmitt: FHWA

Are there any problems recycling through a SAMI?

A - Rowan Peters:

We haven't had SAMI's all that long but we don't expect problems.

A - Jim Scherocman:

A rubberized asphalt test section placed about 1969 in Ohio has an article written on it for AAPT in 1980 about recycling the section.

A - Doug Bernard:

In Arizona one of the first jobs done with a rubber mix rubber did create a slight increase in stack opacity. The rubber was added on the cold feed and fed to the dryer and I guess thats the only trial I am familiar with.

A - Dick Ingburg: Minnesota

In 1977 when we milled pavements we encountered rubber crack sealant. We thought this was a problem so the way we treated it was to have a man remove it before it went through the dryer. If it went through the dryer, it was removed on the hot screens by men wearing masks to protect them from the dust. I think we must rely more on the creativness of contractors to handle the situation.

A - Doug Bernard:

But your talking about cracks and the question was on SAMI. I think this is a considerably different problem.

Q - Lloyd Coyne: Chevron USA

I think it should be noted that the fines in cold mix recycling are locked up with a coating of asphalt and in hot mix recycling are released as the particles are heated and broken down. Therefore, different design criteria must be applied. A question on hot mix recycling-statements on recycled mixes produced at 200 and 210° have been made. Is there any comment on how moisture effects those mixes at this low temperature?

A - Jim Scherocman:

The majority of the mixes are actually 240°F+ and I believe the moisture content of a recycled mix should be no more than that permitted with a conventional mix. You can coat in a drum mix plant by foaming but some material will be uncoated. Generally in a drum mix plant the mix should be hot and have less than 1.0% moisture.

A - Tom Scrimsher:

Lloyd, in California we advocate high mix temperatures such as 260-270°F and we have a 250°F placement temperature. We like hot mixes and we are not going to yield to any low temperature hot mixes in California. Therefore moisture or density problems related to mix temperatures should be practially nonexistent.

Questions & Answers
RECYCLING SEMINAR
Long Beach, California
September 17, 1981

Q. Witco Chemical Co. to Joe Visalia:

Heater scarification - Is it better to work with two machines rather than one machine?

A. Joe Visalia: - Basically its necessary to get pavement heated at as low a temperature as possible. The dwell time is of prime importance, so two machines can provide heat and scarification with a minimum dwell time.

Witco Chemical Co.: - May I suggest an additional factor Joe? One machine takes twice as long and therefore the cost to the user would be more.

Joe Visalia: - I agree, but a final decision should be left to the contractor.

Doug Bernard: - It should be left up to the contractor to make a choice. It may require one, two, or three machines. I have seen occasions when one machine was completely appropriate.

Q. Roger Kocher: Caltrans

Could cold recycled mixes and low temperature hot recycling mix be used effectively if they do not get adequate compaction? And if so, how is this pavement going to perform with low densities?

A. John Wood: - On cold recycling the surface will ravel on all mixes because you don't get 100% coating of the aggregate. So cold mixes must be considered base and must be covered with conventional mix to protect them. What we are trying to do is to increase the structural thickness with cold recycling, so we must have something on the surface of all cold mixes.

Q. Roger Kocher:

Can cold recycling ever be used as a final surface?

A. John Wood: - No.

Joe Visalia: - You are correct about hot recycling. It must be up in temperature or have high enough temperature to obtain proper compaction.

Tom Scrimsher: - Any mix that is poorly compacted will not perform well. A hot type of mix must have sufficiently high temperature to assure adequate compaction. Low temperature with a hot mix will cause crusting in the mix which resists compaction. However, with cold in-place mixes the binder is of low viscosity and of sufficient quantity that it acts like a lubricant and assists compaction. Don't sell cold recycling short. We get some raveling, of course. However, we are improving as we continue with our construction. A most recent project, near Crawly Lake in the eastern part of California was an excellent example of how well we have improved. The cold recycle mix placed on Rte. 395 was used during stage construction as surfacing and produced minimum raveling. We do agree, however, that protective surfacing will be required and will continue to be required when cold recycling is proposed with moderate to heavy traffic. It is possible that a hot recycled mix used as surfacing over a level coarse of cold recycled mix would be a very cost attractive structural section.

Q. Bill Bert: Caltrans

We have a Caltrans requirement limiting the moisture content to 3% for hot recycled mixes. What are the other states doing?

A. Doug Bernard: - 3.0% seems to be somewhat high compared to other states, but I can't say exactly what is common in the other states. I do know that some states are allowing as low as 1.0% for maximum moisture in recycled mixes.

Tom Scrimsher: - Bill, this 3.0% got started originally with the drier drum work when it was felt some moisture was necessary for compaction. Most of our projects have averaged about 1.0% in reality and none have actually been as high as 3.0%. This spec could probably be changed, but at the moments. we don't seem to have had any trouble with it as it now stand

If you have reference to the moisture content of salvaged AC, however, then I would say that probably the 3.0% max. moisture content is probably appropriate and should be retained. Although most salvaged AC will probably have less then 3.0%, occasionally due to rain just before removal or right after stockpiling, it may exceed 3.0%. High moisture content or high fluxuation of moisture during mixing may result in poor aggregate coating. Such a condition may be costly to the contractor because the applied heat may have to be increased.

Q. Should small cities require recycling? And if so, what source is available for the design of the recylced mixes?

Doug Bernard: - We don't want to specifically specify any job to be recycled. We want to permit a contractor to use salvage material in any mix. Thus, the real question should be - Can salvage material be used in any asphaltic mixture?

Joe Visalia: - Caltrans can help in your design. They are as well experienced in this field as any one in the state.

Q. Rick Nelson: Santa Monica

Present specs for the paving machine for placement of a new hot mix require it to be 200 or 300 feet behind the heater planer. Yet, some people say that the paving machine should not be used less than two or three days later. What is your comment?

A. Joe Visalia: - If the contractor had the option, he would probably want to use a two-step, that's two separate step-operation. Due to the problem of maintaining two crews and working in proximity, any breakdown would require a delay of both crews. Therefore, I would expect a two-step operation would be preferable.

Doug Bernard: - One thing that appears missing in this seminar, is that it may be possible in the future to heat, scarify , and mix with one machine in one operation. No speaker has addressed this subject at this seminar, and I feel it is my duty to bring this to your attention now.

Tom Scrimsher: - Doug, this rang a bell with me. I am surprised that Jim Scherocman didn't elaborate on this subject. As a representative of Barber Greene, I am sure that he is aware that his company has a cold milling mixing machine that they consider a prototype. However, it was used in Florida this year. This machine will grind and mix in one complete operation. Except for screeding it will also place a material behind the machine similar to that of a conventional paver. It may possibly be used on a experimental basis on cold recycling jobs in the Bishop area if the contractor who gets those jobs uses Barber Greene equipment.

Q. Jim Epperhart: Escondido

Do heater scarifier machines damage man hole covers?

A. Joe Visalia: - We haven't experienced any problems. We have use various machines and have had no problem with man hole covers. If new machines are developed that force the tynes into the pavement under great pressure, it may be necessary in the future to remove man hole covers or man hole sections to prevent damage. However, presently, we have not experienced that problem. It may be necessary, however, to remove magnetometer loops at intersections or skip the intersection to protect the loops from damage.

Q. Gary Ham: River Construction

When will hot and cold recycling take off?

A. Doug Bernard: - That is difficult to say, except that some 30 states now are recycling. I feel in 1985, hot recycling will be 25% of all hot mix. Cold recycling has been carried on for a long period of time and we are continuing. It will probably increase and there will probably be more cold recycling than hot in the future.

Ray Forsyth: - One of the reasons for this conference was to acquaint and show contractors that recycling can be done with a minimum of effort and cost. Caltrans has frequently presented contracts with an optional bid for hot recycling or conventional mix. Much too frequently the hot recycling option has been rejected, basically because of a lack of understanding by the contractors on how much equipment modification would be required and how much effort would be required for recycling. We hope, therefore, that this seminar will contribute toward educating contractors on what other states are doing with their equipment and the ultimate costs involved with recycling.

Q. Representative from City of Santa Monica:

In 1971, heater scarifiers caused a lot of air pollution and burned shrubs and trees that overhung the pavement.

A. Joe Visalia: - Heaters have been greatly improved since 1971. And although there is still great heat coming from the burners, much of the heat goes up the stack. Very little is now going horizonal which had a tendency, in early times, to burn shrubbery. Due to a better stack arrangement, the air pollution is also minimal.

Q. Representative from City of Santa Monica:

Are you saying then that the trees should be trimmed to 15 feet heights to prevent burning?

A. Joe Visalia: - You're going to put me on the spot. I wish Gordon Whitney was here, I'd let him commit himself. However, I think it could be done safely without trimming the trees. I am sorry I can't give you a more definitive answer at the moment.

Q. Person unidentified:

Is it economical for industry today to modify their plants for recycling?

A. Bill McCullough:

Our company has modified two plants. In 1973 the cost of asphalt was $21/ton - today it's $165/ton. And we still believe that in another few years it will be $200/ton, perhap, even next year. If recycling is proven successful in this area it will increase the activity and there is no question that it can be profitable. Thus, in our opinion, it would benefit the contractor to modify his equipment and be prepared for recycling.

Q. Same unidentified person:

Will the Federal Government subsidize a contractor for plant modifications?

A. Doug Bernard: - Earlier we did subsidize projects. However, now that we have the ball rolling, we don't foresee future subsidizing or money for modifications.

Q. Bill _____: Santa Barbara County

What is the savings for cold recycling over a conventional mix? And how is the cost of recycling in urban areas compared to a conventional mix? What is the savings in general?

A. Ray Forsyth: - We estimate with the work that we have done in general that it will be about a 33% savings.

Doug Barnard: - We should look at the whole life cycle of the recycle mix in order to get a true picture of the entire savings.

Tom Scrimsher: - Bill Bert, what is your opinion? How about the work that you recently completed in the Bishop area?

Bill Bert: - We estimate that we made about a 50% savings on our cold recycling compared to a similar thickness with conventional mix.

Q. Will the fabric used for reducing reflection cracking be a problem in recycling?

A. Ray Forsyth: - Our studies indicate that with on fabric, there will be no problem. However, with some brands there may be a problem. We believe the benefits we're getting from retarding reflection cracking justifies the use of fabrics.

Doug Bernard: - I disagree. I would be damn concerned about fabric in an AC mix if I were to be required to recycle. Contractors have reported problems with fabric when they try to recycle. A conclusion is that the best effort to reduce reflection cracking is surface recycling so fabric isn't really needed.

Tom Scrimsher: - I am, of course, for recycling, but I have a soft spot in my heart for fabric. We have seen it used successfully many times. It appears to me when a pavement has reached the condition where recycling will be necessary that the fabric will have deterioated to the point where it would probably be of very little consequence. If we're going to recycle a mix that is only two or three years old, it may cause us problems if there's fabric involved. But why would we recycle a pavement that is only two or three years old? We have said many times during this seminar that we do not promote recycling just to be recycling. Again, the fabric probably will have deteriorated after fifteen years or so to the point where it will be of very little concern in recycling. Our one project in California in which we successfully removed the fabric by surface grinding for recycling was a project that was only seven years old. So the use of fabric is relatively new today as a construction product. Therefore, it is difficult for me to understand how fabric can be considered a problem at this point, when obviously pavements that have been placed with fabric are relatively new and in no position to be recycled.

John Wood: - I feel there is additional research needed with fabrics. I have encountered fabrics recently that have wrapped right around my mandrel. However, I do confess the jobs were only three years old. I feel that fabric may come back in later years to haunt us if we permit its use.

Q. Person unidentified:

What is the gravel factor assigned for an old pavement to be recycled?

A. Joe Visalia: - We consider a cracked AC as having a gravel equivalent, equivalent to the base, and apply the same factor

Q. From McCullough on the Panel to the audience:

Does the contractor have a responsibility to tell the consumer he is producing a recycle mix or selling a recycle mix? How many feel he has that responsibility? Show me your hands please. How many feel he has no responsibility? Show me your hands please.

(The Yes answer won. Apparently, the audience felt he does have a responsibility to inform the consumer he is using a recycle mix.)

Q. Ted Bishop: Nevada

What is the best way to maintain the quality of a recycled mix if the salvage material is of a very poor quality?

A. McCullough: - The best way is to use a small amount of salvaged AC in the final recycled mix.

Q. Ted Bishop:

What is a general monetary benefit of recycling?

A. Doug Bernard: - Well, if only one contractor is involved, it will cost a considerable amount of money. But with several contractors involved in recycling, it take whatever the market will bear. That's the best way I can put it. It will cost whatever the market will bear.

Tom Scrimsher: - Let us not forget that there is not only an immediate monetary savings in recycling to be realized, but materials definitely will be conserved. Therefore, you are saving aggregate and asphalt when you get into the recycling field. As competition builds up, as Doug just mentioned, the savings to the consumer will increase and the profit to the contractor will increase as he develops equipment and technique.